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# DUAL PRODUCTION SOURCES IN THE PROCUREMENT OF WEAPON SYSTEMS: A POLICY ANALYSIS

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## PREFACE

In an effort to make the weapon systems acquisition process more effective, various agencies within the Department of Defense are considering the increased use of competition during procurement. One means of accomplishing this would be to establish second producers for systems, subsystems, and components and then to have them compete periodically for a portion of the total buy.

An analysis of the implications of such a policy was deemed an appropriate dissertation topic for The Rand Graduate Institute. The research presented here was performed independently and at Science Applications, Inc. under the sponsorship of the Joint Cruise Missiles Project Office and the Naval Material Command.

## SUMMARY

A policy is currently emerging within the Department of Defense that may have a major effect on the weapon systems acquisition process. It involves the establishment of second production sources for weapon systems, subsystems, and components and the implementation of dual source competition where annual production quantities would be divided such that the low bidder would receive the larger share. Advocates of this policy claim it will reduce procurement costs and assure timely delivery and adequate performance by reducing or eliminating certain risks.

This report provides a framework to guide decisionmakers involved with the weapon systems acquisition process in determining whether to establish dual production sources on a case-by-case basis. The framework consists of three main parts: the identification of alternative approaches for establishing second sources and implementing dual source competition; a methodology for estimating costs associated with such approaches together with a review of both relevant microeconomic theories and prior related systems and an analysis of data on competition in the acquisition of weapon systems; and the identification of risks which dual sources might affect and an assessment of their significance.

Limitations existed with respect to both the available data and the analytical methodology. Nevertheless, it was still possible to draw important conclusions regarding the advisability of establishing dual production sources as a general policy.

Since the expectation of cost savings due to competition is the primary reason given for establishing dual sources, it was important both to examine relevant economic theories and to analyze available cost data. Economic theories did not provide a rationale for assuming that dual source competition would consistently lead to lower costs than would a negotiated procurement from a sole source. Rather, they indicated that it is more efficient and, therefore, less costly for one source to produce the entire quantity of an item because it can:

achieve economies of scale, utilize production capacity fully; amortize fixed indirect costs over a broader base; and maximize learning. Also, duopoly theory indicates that each producer will consider the effect it would have on the market and on the other producer in developing a sales strategy. For example, a duopolist may maximize profits either by selling the largest possible quantity or by setting a higher price for the quantity demanded beyond the initial firm's capacity to supply. Thus, efficiency is not a condition for profit maximization under dual source competition.

Even though theory provided no basis for assuming that production cost savings would result from dual source competition, it did not eliminate the possibility. Therefore, available data on past uses of competition were collected and analyzed. In ten cases, the government had held split-buy (i.e., dual source) competitions. Added costs or savings due to competition could be estimated for seven of those cases and four of them showed increased costs. Furthermore, nonrecurring costs required to establish and qualify a second source offset competitive savings or further increased added costs.

Cost data were also collected for items procured through annual winner-take-all competitions. Of the 16 items for which the effect of winner-take-all competition could be estimated, 17 showed savings. Since winner-take-all competitions were generally held between firms with existing production capabilities, they did not require allocations for nonrecurring costs. Thus, all types of competition do not produce the same results: Winner-take-all competitions usually resulted in savings; split-buy competitions often increased costs.

A secondary reason often given for the establishment of a second source is that dual sources would reduce risks associated with a sole source. However, no one had identified those sole source risks which the addition of a second source would reduce nor considered their potential impacts. A second source would reduce the probability that some risks related to the factors of production would be realized. However, those risks affected did not contribute greatly to inadequate performance, schedule delays and cost overruns.

Finally, dual production sources may serve to maintain the country's industrial mobilization base both in general terms and also for a particular weapon system. While this may be a particularly attractive benefit at a time when U. S. industrial preparedness is being seriously questioned, it is necessary to consider mobilization in an appropriately broad context to avoid suboptimization for some subsystems while bottlenecks remain for others.

When applied selectively, the establishment of second sources and the implementation of dual source competition may be effective in lowering procurement costs, in reducing certain risks identified for sole source production, and in enhancing the industrial mobilization base. However, this is not seen as an effective general policy because costs would normally outweigh benefits.

# ACKNOWLEDGMENTS

During the more than five years which have transpired since the inception of work reported in this dissertation, numerous people made significant contributions. Those who should receive special credit are mentioned below.

My RGI dissertation committee, including Michael Rich of Rand, Gregory Carter of the Office of Management and Budget, and Richard Cooper of Coopers and Lybrand (chairman of the committee) reviewed, critiqued, and proposed changes to several outlines and drafts of the dissertation before approving this version. Their suggestions have made the final result better than it would otherwise have been. Fred Hoffman of Pan Heuristics also made important suggestions which are reflected herein. Charles Wolf, Jr. of The Rand Graduate Institute is given special recognition for his support of the effort from the beginning.

Employees of the U.S. Government offices which sponsored portions of this research deserve credit for their willingness to look beyond conventional wisdom and seek a broader understanding of a complex problem. They include (then) Commander Bruce Avery of the Joint Cruise Missiles Project Office and Ron Shames of the Naval Material Command.

Contractor personnel who provided important cost information and openly discussed and debated the implications of particular second source strategies made a significant contribution. They include Eugene Klein of Williams International (then Williams Research Corporation), Richard Snyder of Singer-Kearfott and Si Tenenberg of Litton Guidance and Control Systems.

Colleagues at Science Applications, Inc. assisted in the preparation of this document and in the performance of related research. Specifically, David Jordan assisted with statistical analyses, Karen Shishino typed earlier drafts and C. Susan Anderson prepared the final manuscript and made editorial improvements.

Finally, Susan, who spent years prodding me to get on with it, and family, friends and associates who have continually asked, "Aren't you done yet?" should know that their encouragement has paid off . . . at long last!

Of course, any errors are the sole responsibility of the author.

# ABSTRACT OF THE DISSERTATION

Dual Production Sources in the Procurement
of Weapon Systems: A Policy Analysis
by
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The paper provides a framework to guide decisionmakers involved with the weapon systems acquisition process in determining whether to establish dual production sources on a case-by-case basis. The framework consists of three main parts: the identification of alternative approaches for establishing second sources and implementing dual source competition; a methodology for estimating costs associated with such approaches together with a review of relevant microeconomic theories and prior related studies and an analysis of data on competition in the acquisition of weapon systems; and the identification of risks which dual sources might affect and an assessment of how significant they might be.

Theory and data provide no reason for general optimism regarding cost savings which would accrue from implementing dual source competition. Furthermore, while a second source would reduce some risks related to factors of production, such risks are not major contributors to inadequate performance, schedule delays, or cost overruns. Thus, dual source competition may be an effective procurement strategy for some particular cases but it is not seen as an effective general policy.

Key Words: dual source competition
second sources
weapon systems acquisition
policy analysis
cost analysis
cruise missile

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# I. ORIENTATION

## INTRODUCTION

For many years decisionmakers within the Department of Defense have attempted to reduce the cost and increase the efficiency of obtaining new weapon systems by establishing more effective acquisition policies and procedures. Because of the high stakes involved,[1] even relatively minor successes or failures can have a major impact on costs as well as on the delivery schedule and performance of a weapon system.

A policy is currently emerging that may have a major effect on the weapon systems acquisition process. It involves the establishment of dual production sources for weapon systems, subsystems, and components. Advocates of this policy claim it will reduce procurement costs and assure both timely delivery and adequate performance by reducing or eliminating certain risks. This report assesses the manner in which dual sources may be established and considers their effect on cost, risk, and other issues associated with the acquisition of weapon systems. It seeks to provide a framework that will guide decisionmakers involved with the weapon systems acquisition process in determining whether to establish dual production sources on a case-by-case basis, so that costly errors will not result from inadequate planning.[2]

Before proceeding with the discussion of dual production sources, the following paragraphs provide a brief overview of relevant aspects of the weapon systems acquisition process and introduce several terms which appear frequently throughout the remainder of this report. This will

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[1]During fiscal year 1981 over $40 billion was budgeted for military research and development, and procurement.

[2]In addition to having major ramifications for the acquisition of weapon systems within the United States, the establishment of dual production sources also relates directly to international coproduction programs which involve producers from two or more countries as a way of achieving rationalization, standardization, and interoperability (RSI) objectives within NATO. Therefore, much of this report may also be germane to analyses related to international coproduction programs; however, no attempt is made to deal with that topic explicitly, as it is beyond the scope of this endeavor.

provide an appropriate context in which to consider the proposed use of dual sources.

The weapon systems *acquisition* process consists of two phases: *research, development, test and evaluation* (referred to as RDT&E or, simply, R&D), and *procurement*. The RDT&E phase involves the perception of a requirement and the identification and evaluation of alternative means for satisfying it. The RDT&E phase usually involves more than one firm until after the completion of prototype production and testing. The "best" design is selected during RDT&E and the procurement phase begins with full scale production and continues until the final unit has been built.

During the procurement phase, the government usually awards a contract annually for the production of a specific quantity. Because the developer of a complex system has unique capabilities and experience, the government frequently awards it a *sole source* production contract; the *price* it receives is based upon production *cost plus a profit*.

For relatively simple items required in large quantities, the government often has established annual competitions[3] among qualified bidders, awarding the entire quantity for that year to the low bidder (or source otherwise judged most advantageous to the government). Such competitions are referred to as *winner-take-all* because firms other than the winner receive no award. If the low bidder is not the developer (or *initial source*) of the item, it is referred to as a *second source*.

Because implementing competition has realized substantial savings for certain items, the government has sought to expand the competitive procurement of weapon systems. However, a major impediment exists: Technically complex systems (e.g., turbine engines, airplane and missile airframes, and sophisticated electronics) usually require expenditure of substantial start-up costs over a long period of time to qualify a second production source and maintenance of continuous production once a second source qualifies. Therefore, it is not feasible to establish annual winner-take-all competitions for such items. *Dual source competition* has been proposed as a solution to this problem. This would

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[3]The various means of implementing competition in the procurement of weapon systems are summarized in Chapter II.

occur after the successful establishment of a second source and would involve annual competitions in which the low bidder receives a contract to produce the larger quantity and the high bidder a sufficient quantity to maintain a viable production capability. This procedure is referred to as a *split-buy* competition.[*] In addition to lowering procurement costs, defense decisionmakers also perceive that dual sources will reduce certain risks inherent in a sole source and will enhance the industrial mobilization base.

Since winner-take-all competitions among several producers may be implemented readily for many items that are not technically complex, split-buy competitions between dual sources would probably be limited to items requiring significant start-up costs and long lead times to establish a second source. Such items would tend to be major weapon systems, and their subsystems and components. A policy altering the manner in which the government procures such items could yield major benefits or cause significant problems and, therefore, should be based on sound analysis rather than conventional wisdom. The body of this report provides theory and data related to such a policy together with an analytical framework for applying them in making decisions concerning the policy's implementation. However, before discussing this framework, the following section charts the evolution of dual source competition as an emerging weapon systems acquisition policy and describes its first major test on cruise missile subsystems.

## BACKGROUND

The evolution of the use of second sources to establish dual source competition and to reduce risks associated with sole sources has been a gradual, step-by-step process. Furthermore, its emergence as a weapon system acquisition policy has been informal. Documenting the emergence and initial application of this policy provides a historical perspective for the analysis which constitutes the body of this report.

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[*]Split-buys also may be noncompetitive, as in the case of *educational contracts* in which the government may award a small quantity to qualify a second source as a producer.

## The Emergence of Second Sources

The government established the first second source shortly after World War I to generate design competition when it funded Chandler-Groves to develop a floatless carburetor following unsuccessful attempts to enlist the cooperation of Stromberg-Carlson (which had a virtual monopoly on carburetors for aircraft engines). As a direct result of this action, Stromberg-Carlson doubled its engineering budget and produced the pressure carburetor used on all U.S. high powered aircraft engines in World War II.[5] Thus, the competition created in this case enabled the government to achieve its technical objective.

The government also established second sources when a single production source could not produce the quantity required because of capacity limitations. The production of B-47s during the Korean War provides such an example:

> Upon the opening of hostilities in Korea in 1950, the Air Force had determined that the B-47 bomber represented its chief deterrent weapon with respect to threatened attack on the United States by an enemy country. It thereupon expanded its order of B-47s. It adopted a policy which required that they be manufactured not only by Boeing in Wichita, Kansas but by Lockheed Aircraft Corporation and Douglas Aircraft Company in their factories situated elsewhere than Seattle or Wichita.[6]

To accomplish this, Boeing served as the prime contractor and provided Lockheed and Douglas with tooling, technical data, knowhow, and components and parts.

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[5]Morris Zusman, Norman Asher, Elliot Wetzler, Debbie Bennett, Selmer Gustaves, Gerald Higgins, and Carole Kitti, *A Quantitative Examination of Cost-Quantity Relationships, Competition during Procurement and Military versus Commercial Prices for Three Types of Vehicles*, Volume II, Institute for Defense Analysis, AD-784 335, March 1977, p. 47.

[6]*Hearings before the Subcommittee on Economy in Government of the Joint Economic Committee*, Congress of the United States, Ninetieth Congress Second Session, Part 2, U.S. Government Printing Office, Washington, D.C., 1968, pp. 181-182.

In the late '60s the establishment of second sources to create competition was first defined in the literature:

> Another method for obtaining competition [at] the reprocurement level is "second sourcing". . . . Usually the underlying R&D is performed by a single firm. . . . During the initial production run or during follow-on production, or both, there is some form of competition.
>
> . . .
>
> The new second source sets up a production line. Production by the original and second source may overlap in time, two production lines may be maintained through much of the program, or the original source may drop out of the program, with the award of the contract to the new supplier.[7]

More recently, it was recognized that dual sources also might prove effective in reducing risk:

> In several instances we found that competition was maintained or reintroduced (often through the technique of dual sourcing) in order to lower prices and to provide backup capability in case one firm had serious technical problems.[8]

Thus, the government established second sources initially to stimulate design innovations and later to increase mobilization capabilities during wartime. More recently, analysts have recognized the potential of establishing second sources to create procurement competition and of retaining dual sources to reduce risk.

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[7]G. R. Hall and R. E. Johnson, *Competition in the Procurement of Military Hard Goods*, The Rand Corporation, P-3796-1, June 1968, p. 31.

[8]Geneese G. Baumbusch and Alvin J. Harman, *Peacetime Adequacy of the Lower Tiers of the Defense Industrial Base*, The Rand Corporation, R-2184/1-AF, November 1977, p. 25.

**Foundations of Current Second Source Policy**

Despite recognition of the potential for creating ongoing procurement competition by establishing dual production sources together with other benefits including the reduction of certain risks, there is no evidence that any general DoD policy related to dual sources was initiated prior to the Carter Administration. An initiative by the director of a system program office (SPO) resulted in individual cases where second sources were established and yielded ongoing competition. Even though the Carter Administration made the development of dual sources to establish competition and reduce risk a cornerstone of its weapon systems acquisition policy and the Reagan Administration has continued to advocate it, neither Administration has promulgated an official statement (such as a DoD Directive) of this policy. Rather, the basis for, and existence of, this policy must be inferred from a series of speeches and other documents.

William Perry, while Under Secretary of Defense for Research and Engineering, explained some of the Pentagon's ideas and motivation for experimenting with the establishment of second sources:

> Under current practices, several companies often receive contracts to design a new plane or missile. Next, for most weapons two companies receive advanced-development contracts under which they build prototypes. A production contract is then awarded to one of the companies on the basis of its prototype's performance and the cost estimates it submits to build the weapon. Thus, competition stops when production begins. The idea behind the new plan is "to maintain a competitive environment even through the manufacturing process," Mr. Perry explains.
>
> . . .
>
> "We aren't talking about giving the first few years (of production) to one contractor and the last few years to another," he explains. Instead, the Pentagon wants to be able to compare costs and "determine on a year-to-year basis whether it will be a 50-50 or 70-30 division of the business between the two competitors," he said to illustrate.

. . .

> Mr. Perry concedes that the Pentagon may be "trading off" the benefits of big production contracts which promise certain manufacturing efficiencies, for the anticipated cost discipline of competition. But "there's an absence of quantitative data" on this, he says.
>
> In favor of dual manufacturing, Mr. Perry notes that the current "winner-take-all" system leads to "feast or famine" for many defense contractors. "If we can reduce the feast or famine aspect of working for the government, we will be doing industry a great service" by reducing some of the uncertainties of undertaking highly complex weapons development work, he says.[9]

Excerpts from a speech Charles W. Duncan, Jr. made while he was Deputy Secretary of Defense further document this thinking:

> Naturally, we would like the development process to be competitive. Where costs permit, we would prefer to have the competition go beyond paper studies and as far as prototypes, where that is too expensive, we would still like to see more competition at the component-level. . . Prime candidates for continuing competition right now are the cruise missile and its various subsystems. . . .
>
> Where competition does take place, the current practice is pretty much "winner take all." We plan to change that. . . .the procedure used by IBM with its suppliers is particularly attractive where large quantities of goods are needed. Under this procedure, the winning bidder receives more than half of the order, and the closest competitor gets the remainder. When the next order comes up, the competition becomes even sharper, as number two tries to become number one. . . .[10]

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[9]Kenneth Baron, "Pentagon to Try Awarding Contracts for Same Weapon to Two Manufacturers," *Wall Street Journal*, November 21, 1977.

[10]Charles W. Duncan, "Remarks before West Coast Dinner of National Industrial Security Association, Beverly Wilshire Hotel, Los Angeles, California," Office of Assistant Secretary of Defense (Public Affairs), January 26, 1978.

Longstanding formal DoD policy concerning procurement priorities is also related to dual source policy. This policy gives critical national security programs top priority regarding access to key resources if a shortage occurs. The DoD Master Urgency List (MUL) identifies the relative ranking of high interest military programs and inadequacies in the industrial base that affect the most urgent programs. A BRICK-BAT designation on the MUL indicates a program has the highest national priority for industrial resources and has been approved by the President. Because of their high priorities, BRICK-BAT programs are prime candidates for dual sources.

Thus, the desire to stimulate competition in the procurement of weapon systems, coupled with the recognized need to expedite and assure the production of high priority weapon systems, serves as the basis for the emerging dual source policy.

### A Test Case: The Cruise Missile

The cruise missile, because of its recognized importance (it has received the BRICK-BAT designation), imminent procurement, and the emphasis that the Joint Cruise Missiles Project Office (JCMPO) management placed on cost control, was the obvious candidate for investigating and experimenting with alternative means of defining and implementing second source policy.

In fact, when DoD established the JCMPO on January 14, 1977, to manage the entire cruise missile program on behalf of both the Navy and the Air Force, then Deputy Secretary of Defense W. P. Clements noted in his DSARC II Direction that the JCMPO

> is to maximize subsystem/component commonality and quantity buy, . . . to encourage subsystem/second source competitive procurement. . . .

Captain (later Admiral) Walter M. Locke further explained this emerging policy in hearings before the House Armed Services Committee:

> There are three categories of risk. Cost, Schedule and Technical. . . . Cost risk and risk in general is minimized through the element of competition on the air launched program. We plan to further drive our risk down through an aggressive second sourcing plan on our critical subassemblies.[11]

The cruise missile[12] sustainer engine was the initial subsystem considered to determine whether the establishment of a second source would be appropriate and, if so, how it could best be accomplished. The USAF Aeronautical Systems Division voiced specific concerns related to risks in procuring the sustainer engine, as described in the following quotation from their study:

> With recent major decisions pertaining to the U.S. defense program, the Cruise Missile Development Program has taken on a key role. This emphasis has forced a deep look at the contingency options as related to acquisition of Cruise Missile Systems and components. One area of concern is with the Engine Contractor for the Cruise Missile, Williams Research Corporation of Walled Lake, Michigan. To date Williams Research has performed in a highly satisfactory manner, and there is no reason to believe that this performance will not continue. However, Williams Research has never demonstrated a capability to produce engines of this complexity in the quantities that will be required. Recent management and production planning analysis indicates that the contractor should be prepared to perform. Notwithstanding; Williams Research is a Small Business, and currently has the bulk of its industrial capability under one roof. This leaves it vulnerable to acts of nature, labor disputes, etc. In addition, although technical feasibility has been demonstrated, some engineering problems await final resolution. Accordingly, a study has been directed to

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[11]Hearings on H.R. 8390, September 9, 1977, p. 283. The term, "subassembly," is key in understanding this policy, as the government generally acquires major weapon systems from a prime contractor which may manufacture certain components, acquire others from subcontractors and vendors, and integrate them with still other equipment furnished by the government (GFE). Thus, to assure dual sources for critical items on major weapon systems, the policy would have to be implemented at levels below that of the complete system.

[12]The generic term, "cruise missile," is used here and throughout this report, rather than Tomahawk, ALCM, or GLCM, as the engine and guidance subsystems which are discussed are applicable, with some modifications, to all versions.

> determine the options open to the Government to assure that Cruise Missile engines will be available to meet the need of the production program.[13]

That study addressed four options for assuring delivery of the cruise missile engine and recommended two of them for implementation:

- Development and production of an alternative engine with identical form and fit but slightly improved performance with respect to specific fuel consumption and thrust.
- Direction of Williams Research to develop second sources for all critical components and major subcontracted subassemblies or parts.

Subsequently, the Commander of the USAF Systems Command requested that JCMPO conduct another study to determine

> whether or not the costs to develop a second source could be overcome by the advantages of a price competition for some split of production requirements. . . . As a minimum this study should quantify the following:
>
> a. Estimated cost of developing, qualifying, and producing the proposed second source modified development engine.
> b. Projected production costs for the Williams cruise missile engine.

The conclusions should state whether developing a second source for the Williams engine is practical and/or desirable at this time from a cost benefit perspective.[14]

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[13]F107 Joint Engine Program Office, *Development of Second Source for Cruise Missile Propulsion*, ASD Wright Patterson AFB, Ohio, August 1977, p. 1.

[14]Colonel Raymond C. Preston, Jr., USAF, Assistant DCS/Procurement & Manufacturing for the Commander AFSC, "Letter: Request for Second Source Cost Benefit Analysis," addressed to Joint Cruise Missiles Project Office (JPM-3), AFSC Andrews AFB, Washington, D.C., January 12, 1978.

Science Applications, Inc. (SAI), under its contract to JCMPO to perform cost and policy analyses, was directed to perform this study. SAI defined the issues and performed the required analyses that suggested another apparently more cost effective alternative: production of the Williams engine by Williams and a second manufacturer to be selected. This alternative dominated the others identified for the engine case.

JCMPO management perceived that the implementation of dual source competition would benefit other key cruise missile subsystems and sought to expand its use. The guidance system was considered next. It provided a situation where many of the assumptions applied to the engine were not valid and where a different set of constraints existed. Together, the cruise missile engine and guidance system cases virtually bound the second sourcing issue. The following chapters reference and discuss both the cruise missile engine and guidance system studies to document the practical application of concepts and methodologies developed therein and introduced below.

## ANALYTICAL FRAMEWORK

Because a decision to increase substantially the use of dual production sources in the acquisition of major weapon systems could have significant effects, it is important to identify, define and analyze key issues. A number of questions, including the following more significant ones, must be raised:

How can second sources be established?

How can competition be implemented between dual sources?

How would two producers affect recurring production costs if they did not compete?

How would dual source competition affect recurring production costs?

How should the total cost impact of dual sources be assessed?

What types of risk are of concern in the acquisition of weapon systems and how would dual sources affect them?

How would dual sources affect industrial mobilization capabilities?

To answer these questions comprehensively it is essential to be cognizant of several different bodies of knowledge, including: laws and policies related to defense contracting, rights in technical data, and licensing; microeconomic and decision theories; methods for performing resource and risk analyses; and the weapon systems acquisition process. Each of these was considered in the development of a conceptual framework for evaluating the complex implications of dual production sources. The body of this report presents this conceptual framework and discusses how it relates to actual dual source decisions made regarding key subsystems on the cruise missile. An overview of this conceptual framework is presented below. It consists of three main parts: the identification of alternatives for establishing second sources and implementing dual source competition; a methodology for estimating costs associated with the establishment of second sources and implementation of dual source competition, a review of relevant microeconomic theories and an analysis of data on competition in the acquisition of weapon systems; and the identification of risks which dual sources might affect and an assessment of how significant they might be.

## Alternatives for Dual Source Competition

Second sources may produce an item identical to that manufactured by the initial source or one which performs the same function and meets the same specifications. The government can use several methods to implement competition. The type of second source it establishes and the means by which it implements competition may significantly affect program cost, schedule, and risk. Chapter II defines these alternatives and considers how types of second sources and means of implementing dual source competition interact.

### Costs

The desirability of establishing second sources depends closely on the expectation that the resulting competition during recurring production would reduce total cost. Since establishing second sources would require greater costs at the outset, the key analytical issue is whether competition would reduce recurring production costs enough to offset the higher initial costs and potentially greater support costs. To determine whether it is reasonable to anticipate recurring production cost savings in particular cases, Chapter III presents a theoretical foundation for dividing production between two firms and potential outcomes of dual source competition together with analyses of data contained in empirical studies on competition in the procurement of weapon systems.

### Risks and Other Issues

Dual sources might reduce the probability that certain types of risk associated with the various factors of production (including technical information, management, labor, and plant and capital equipment) would be realized, thereby impairing performance, slowing the schedule, or increasing cost. Although these risks are difficult to quantify (i.e., by specifying the probability that they will occur and the resulting damage in terms of cost and/or schedule delay if they did occur), Chapter IV provides subjective methods for evaluating risks associated with a sole source together with a discussion of how alternative types of dual sources might affect them. That chapter also discusses other issues related to dual sources which may be significant in particular cases (maintaining or expanding the mobilization base is one frequently mentioned).

Chapter V summarizes the significant findings presented in the previous chapters. It also organizes and presents issues which should be addressed before establishing a second source and implementing dual source competition.

In summary, the body of this report identifies means of establishing second sources and implementing dual source competition and provides a conceptual framework for analyzing their probable effect on

costs and risks associated with specific cases. This framework should aid decisionmakers considering the establishment of second sources by raising important considerations and by providing a context for resolving them.

# II. TYPES OF SECOND SOURCES AND MEANS OF IMPLEMENTING COMPETITION

There are two general types of second sources and several potential means of implementing competition between them and the initial source. The type of second source selected and the means by which competition is implemented may significantly affect cost and risk.

Identification and discussion of types of second sources and definition of means for implementing competition together present the range of potential options available to the government for establishing dual source competition. Choices available to the government for establishing dual source competition in the cruise missile program are described as examples of how circumstances related to particular cases may severely limit the range of potential options and of how prudent early planning may preserve options.

## TYPES OF SECOND SOURCES

Second production sources may be characterized by their output in comparison with that of the initial source:

1. Identical Item. A second source may produce an item identical to that produced by the initial source.
2. Alternative Item. A second source may produce an item that performs the same function and meets the same specifications as that produced by the initial source.

The first type involves one design; the second type involves two designs.

On occasion, the government has considered a third type of "second source": the establishment of redundant production facilities and/or suppliers by a sole source. While "redundancy" reduces certain risks, it precludes competition because only one firm is involved. Since it is at best a quasi second source, it is not discussed further.

### Production of the Identical Item by a Second Source

The most common type of second source is one which produces an item identical to that produced by the existing source. To accomplish this, the second source must obtain technical information related to the design and production of the item. This may be done by acquiring technical data from the developer or the government, or by "reverse engineering," that is, by developing design and process data from the item itself. Thus, the availability of technical data is the primary determinant as to whether a second source may be established to produce an identical item. (Technical data are discussed in Appendix A.)

### Production of an Alternative Item by a Second Source

The design, development, and/or production of an alternative item is another means of providing a second source. At the subsystem or component level it is essential that the alternative have the same form and fit as the original in order to insure physical and functional compatibility with related subsystems or components. Therefore, form, fit, and function (F3) specifications require that specific performance characteristics and physical, electrical, and environmental interchangeability with prior items be achieved. However, the internal design of the alternative item does not have to be identical to the existing internal design.

If form and fit were not identical, extensive redesign costs to assure compatibility probably would eliminate the producer of an alternative item as a potential second source on economic grounds. However, the freedom to change internal design permits technological advances to be incorporated, reliability to be improved, and economical changes to be effected.

The lead time and expenditure necessary to have an acceptable alternative design ready for production may vary greatly depending upon the level of technology required and the number of firms competing. While alternatives for some subsystems may be obtained only with heroic efforts, others may be readily supplied using technology that is predominantly off-the-shelf.

## IMPLEMENTING COMPETITION

Several means of implementing competition are available to the government. Each is described briefly below.

### Formal Advertising

The most competitive form of procurement is formal advertising, whereby interested and qualified bidders are sought and provided with a detailed and accurate data package. (The implementation of this option for an alternative item is conceptually possible, as the government could provide complete performance specifications in lieu of a data package. However, accomplishing this would become more difficult as design complexity increases.) After studying the data package, the bidders submit a sealed bid containing a unit price for which they will supply the required item. A fixed price contract is awarded to the lowest bidder.

Formal advertising is not appropriate for complex items where a data package may not be adequate for preparing a bid or successfully producing an item, or where the government must be able to evaluate the technical capabilities of a firm.

### Two Step Formal Advertising

A variation of formal advertising--two step formal advertising--adds the extra step of requiring a technical proposal so that the adequacy of a firm to produce the required item may be determined. After technical proposals are received and reviewed, invitations to bid are given only to those firms deemed technically adequate. While two step formal advertising discourages less qualified firms from submitting proposals, and enables the government to screen the technical capabilities of prospective bidders, firms are often reluctant to submit fixed price bids for items with which they have no production experience.

## Competitive Negotiation

Competitive negotiations are used in lieu of formal advertising in establishing second sources when data packages are ambiguous or incomplete, or performance specifications are difficult to define such that claims against the government for cost overruns incurred by the winning contractor would probably result. Competitive negotiation may be implemented in lieu of formal advertising only if one or more of 17 conditions specified in the *Defense Acquisition Regulations* (DAR) exist. Technical, management and cost proposals are solicited for required work and, after they are received, negotiations are conducted with those firms whose offers are considered technically acceptable and whose estimated costs fall within a reasonable range. In negotiation, unlike formal advertising where only fixed-price contracts are awarded, the contracting officer may use a fixed-price, incentive, or cost-reimbursement contract.

Since two firms may be kept in production concurrently, competitive negotiation is an alternative for establishing dual source competition. It minimizes risks to both the firm (it may acquire production experience before submitting a fixed-price bid) and to the government (by establishing concurrent production for the initial source and assuring timely delivery by the second source).

## Educational Contract

When an adequate data package does not exist, only a very restricted number of qualified contractors is available, or the item to be produced is very complex, educational contracts for a small lot are sometimes awarded so that a second contractor can perfect its operations sufficiently to enable it to compete with the existing source. When an identical item is involved, educational contracts generally have a higher unit cost than the existing sole source contract. However, for this added cost, a qualified second source is established which presumably is capable of competing with the existing sole source. Thus, an educational contract is an intermediate step in introducing competition into the procurement of weapon systems. It may be used in conjunction with competitive negotiation, directed licensing, or leader company procurement.

## Contractor Teams

An emerging strategy for introducing competition into the weapon systems procurement process is to award design contracts to teams of contractors. The contractor team with the winning design will receive a production contract so that both firms may demonstrate an independent production capability. After the initial award, competition between the two firms takes place.

Although this practice is only just being tried by the Navy for the development and procurement of the Airborne Self-Protection Jammer, certain advantages and disadvantages may be anticipated. Each source would enter procurement competition on an equal basis as each would have complete knowledge of the design and manufacturing process, and each would have produced the same initial quantity. The fact that two firms would cooperate in the development phase would be an advantage in that diverse backgrounds may be applied to a problem; however, firms may be reluctant to share proprietary information with their competitors.

## Directed Licensing

Directed licensing is implemented by making a provision in the R&D contract to allow the government to transfer design data and production technology from the developing firm to another firm selected or approved by the government at a later time. Any lump-sum payments or royalties for the transfer of technology would be predetermined and stipulated in the R&D contract, before the developer has accumulated advantages that enable him to bargain as a monopolist.

In directed licensing, technical assistance[1] is provided by the developer to aid the new producer in getting started. The absence of the technical assistance feature in the types of competitive procurement discussed above often limits their application to items of less than high complexity.

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[1]Technical assistance includes information, materials, and services of the following types: specifications, designs, and production techniques; planning and construction of plant facilities; purchase and installation of machinery and equipment; training of licensee personnel; adaptation of products and production technique; and engineering and consultant services and advice.

### Leader Company Procurement

Leader company procurement is recognized as an extraordinary procurement technique in which the developer or sole producer of an item (the leader company) furnishes manufacturing assistance and knowhow or otherwise enables a follower company to become another source of supply. It is similar to directed licensing in that technical assistance is provided by the developer. It differs from directed licensing, however, in that it requires that the leader company produce the item in parallel with a follower company while directed licensing offers the possibility of no follow-on production for the leader.

There is a potential range of government responsibility within leader company procurement. It may contract with both the leader and follower companies or with only one, in which case the other would be a subcontractor. The extent to which the government relinquishes its authority to the leader by enabling it to select and contract directly with the follower may limit the rigor of any subsequent competition.

The types of competition discussed above are displayed in Figure 2.1, together with general observations related to factors limiting their application (i.e., data rights and complexity of design in general), responsibility in the use and selection of a second source, and the degree to which they foster competition.

The availability of some means of implementing competition may be restricted, depending upon the type of second source established. The first three alternatives (formal advertising, two step formal advertising, and competitive negotiation) could be used for either identical or alternative items. The final four alternatives (educational contract, contractor teams, directed licensing, and leader company procurement) generally are restricted to establishing competition in the procurement of an identical item. However, an educational contract could be awarded so that a second source producing

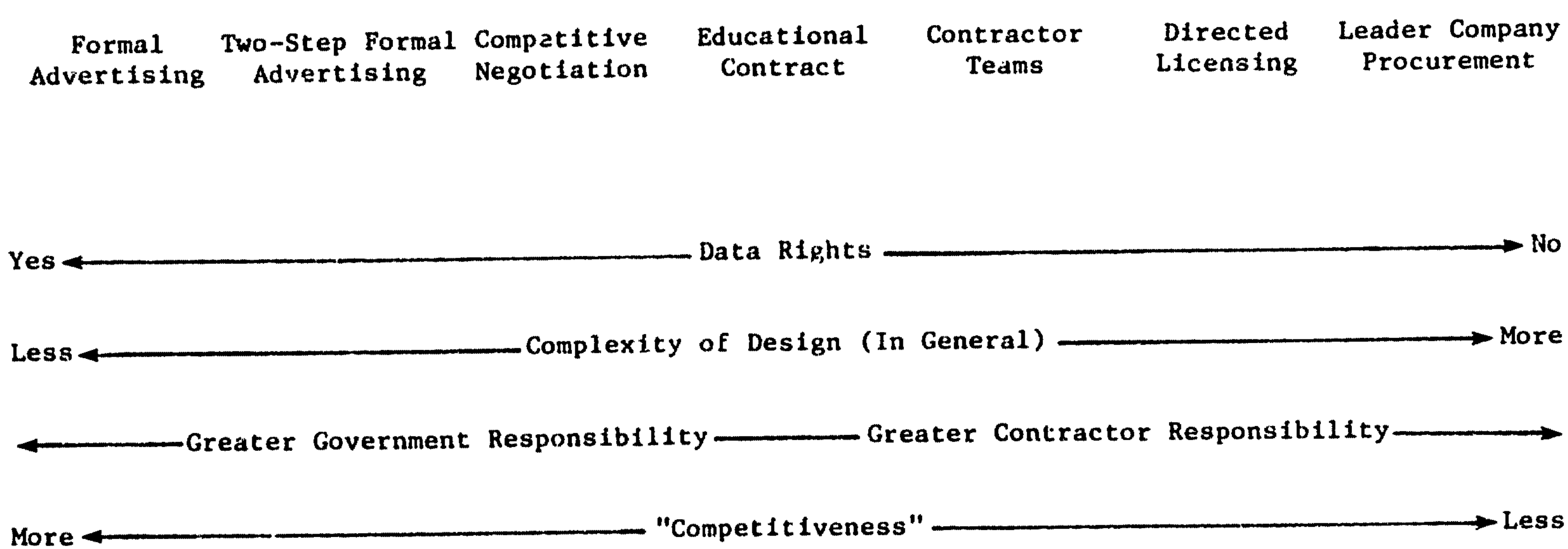


Fig. 2.1--Alternatives for implementing competition

an alternative item could demonstrate its capability.

The type of second source is restricted in turn by characteristics of the item being acquired and the disposition of data rights.[2] Often these two factors are interrelated. If the design of an item is simple, it may be amenable to reverse engineering such that data rights would not be an issue. On the other hand, if the design of an item or manufacturing technology required to produce it is extremely complex, a second source may not be able to produce it successfully (even with complete technical data) unless the initial source provides effective technical assistance. As noted, dual source competition is most appropriate for items which are relatively complex.

The alternatives for creating competition might be viewed as a progression on Figure 2.1, as the responsibility of the government decreases from left to right while the responsibility of the contractor increases. In the case of formal advertising there is no participation by the initial source whereas the initial source may continue as the prime contractor under leader company procurement. Bidders are completely independent of one another in formal advertising and competitive negotiation but there is at least some cooperation between the two sources in contractor teams, directed licensing, and leader company procurement. As the responsibility of the government increases, so does the openness and aggressiveness of the competition. Thus, it is anticipated that the greatest savings would be realized from competition implemented through formal advertising and that the least would result from leader company procurement.[3]

The alternatives that give the government greater responsibility (formal advertising, two step formal advertising, and negotiated competition) can be implemented only if the government has the right to use the technical data produced by the developer of the item. Thus, it is essential that the government consider the data rights issue at the

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[2]Data rights refer to the ability and legality of one firm acquiring and using data related to engineering, technical, and manufacturing features of another firm's design. The data rights issue is discussed in Appendix A.

[3]Price/quantity equilibriums that result from different types of markets are discussed in Chapter III.

outset of any weapon system acquisition program. If this issue is not resolved early, the government may be precluded from implementing certain alternatives for establishing competition. In fact, second source alternatives for key cruise missile subsystems were limited severely because the government did not acquire data rights.

## IMPLEMENTING DUAL SOURCE COMPETITION FOR THE CRUISE MISSILE

Types of second sources and alternatives for implementing competition were discussed above. It was noted that planning must take place at the outset of the R&D phase to secure the cooperation of the developer with respect to data rights and technical assistance. Otherwise, the position of the developer is strengthened significantly in any ensuing negotiations and, therefore, certain alternatives for implementing competition during procurement may be eliminated.

Because the government did not acquire data rights in the cruise missile program, the subsystem developers had significant leverage in influencing the type of second source selected and the manner in which competition was to be implemented. Specifically, second sources were selected to produce identical items for both the cruise missile engine and guidance systems. Furthermore, competition was implemented for both subsystems by using leader company procurement.

The use of an alternative item to provide a second source may be accomplished with relative simplicity if such an item already exists* or with great difficulty if such an item must be developed. The development of an alternative engine and an alternative guidance system for the cruise missile provides examples from both ends of the spectrum (relatively difficult to relatively easy). Similarly, the importance of data rights in enabling the government to establish a second source to produce an identical item varied from critical (engine) to relatively unimportant (guidance system).

In both the engine and guidance system cases, the government sought to establish a second source that would not require large start-up costs or cause high schedule or technical risks. These criteria may, however, have reduced the aggressiveness of competition during the production

*Alternative items may exist when design competition has occurred during RDT&E or when the item is not unique to a particular system.

phase. The relevant background of the establishment of second sources is presented below for the cruise missile engine and guidance system to provide examples of issues encountered in actual cases.

## The Cruise Missile Engine

The government recognized two potential types of second sources in the case of the cruise missile engine: an identical item (the establishment of a second source to produce the F-107 engine which was developed by the Williams Research Corporation [WRC]) and the development and production of an alternative engine (known officially as the Alternate Cruise Engine [ACE]). The government preferred to establish a second source to produce the F-107 because WRC was deemed to be technically superior to firms which would compete for the development of ACE and because it could avoid a long, costly, and risky R&D program. Specifically, even if an expenditure of $40 to $80 million over a period of three to five years was made to develop ACE, it was questionable whether ACE would be technically equal[5] and able to compete economically with the WRC engine. However, because WRC claimed proprietary data rights in its engine design, the government was faced with the possibility of a long legal battle to determine rights to the disputed data and/or paying an unacceptably high cost to WRC to obtain unlimited data rights in order to assume full responsibility for establishing a second source and implementing dual source competition.

It was anticipated that any legal resolution of the data rights issue would be protracted and, therefore, would eliminate any potential financial savings that might result from competition between two sources for the WRC design. Thus, the development of ACE was seriously considered by the JCMPO as a means of obtaining a second source for the engine. While recognizing that ACE probably did not provide a

[5]Actually, government plans called for ACE to be superior to the existing WRC engine as "modest" design improvements were included in the draft ACE RFP (WRC also was to receive funds to make comparable improvements). These improvements included increased thrust (20 percent) and range (by reducing specific fuel consumption), and reduced maintenance requirements.

The possibility of achieving competition was diminished by the fact that the first ACE unit would be produced at about the same time as unit 2000 of the F-107, thereby giving WRC a virtually insurmountable learning advantage.

significant competitive threat for production of the cruise missile engine, WRC management apparently viewed the award of millions of federal R&D dollars to a competitor as the greater of two evils over the long term and, therefore, was willing to participate in a leader company procurement.

An agreement for a leader company procurement was reached which provided the government with two production sources for the F-107 engine and gave WRC a role in selecting the recipient of its trade secrets, as it would select (subject to government approval) a follower to serve as a second source in producing its engine and prepare a license/technology transfer arrangement. Prior to producing a fully qualified engine, the follower would serve as a subcontractor to WRC. Thus, WRC, in effect, would be able to trade design technology for manufacturing technology by selecting a follower whose strength was in that area.

WRC was able to negotiate from a position of strength because its design was years ahead of its potential competition from a technical standpoint and determination of the ownership of data rights was deferred in negotiating the development contract for the F-107 engine. Given that WRC would not be a sole source for the production of all cruise missile engines, a leader company procurement represented the next best alternative from its viewpoint.

### The Cruise Missile Guidance System

The establishment of a second source for the cruise missile guidance system illustrates a different set of issues. The McDonnell Douglas Astronautics Company (MDAC) was the prime contractor for the cruise missile guidance system. However, MDAC itself manufactured only an insignificant amount of hardware while acting instead as the system integrator by developing the required software and selecting subcontractors to provide key hardware items.

Litton Guidance and Control Systems (LG&CS) was the initial source for key hardware components, including the reference unit, computer, and power supply (which are collectively referred to as the RMUC). While LG&CS was willing to serve as a leader from the outset (with certain restrictions which are noted later), there was general agreement that LG&CS did not have uncontested technical superiority in the inertial

navigation field but rather manufactured systems that were essentially equal in performance to those of its major competitor, Singer Kearfott (SK). Furthermore, the key component of the cruise missile RMUC is the inertial platform, which is basically an off-the-shelf item.[6]

Thus, the government had two reasonable alternative second sources to consider for the RMUC: an alternative item to be provided by SK and an identical item to be produced by a follower to LG&CS. When an identical item to be provided by Litton Systems Limited of Canada (LSL) as a follower to LG&CS was selected, SK filed a formal protest with the General Accounting Office (GAO). The hearings lasted for over seven months and raised many important issues regarding the procurement process in general and the establishment of second sources in particular.[7]

The basic question presented by the Singer protest was whether the competition, based solely on form, fit, and function proposals, was properly canceled in favor of a sole-source contract based on a licensing arrangement. Singer made several arguments based upon procedural shortcomings and unfair and discriminatory actions on the part of the government and MDAC. However, its most important argument was that there would be no real price competition between LG&CS and LSL since both were part of the same corporate entity and that the government would only assure true competition by having a completely separate firm compete with LG&CS for the production requirements.

Although these arguments were disputed by Litton, MDAC, and the JCMPO, in the end none of them proved to be important since the GAO decision underlined the authority of the government program manager. Specifically, the JCMPO argument, "that only through the licensing approach can the goal of commonality for the subsystems be obtained,"[8] was insurmountable despite Singer's documentation of a statement by

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[6]There is significant precedent for alternative avionics on aircraft, as illustrated by the Air Force F3 program for medium accuracy inertial navigation systems and commercial airlines which tend to standardize the avionics on their aircraft. This may be contrasted to the fact that fitting an aircraft for different engines is a complex engineering effort (unless they are wing mounted).

[7]For complete documentation of this case, see: Comptroller General of the United States, *Matter of Singer Company, Inc., Kearfott Division*, File B-193270, June 6, 1979, pp. 3-5.

[8]Ibid., p. 8.

JCMPO that "common should not be read as meaning exactly the same" and that commonality therefore does not require that the second source produce the identical item supplied by the other source.

The GAO finding included the following statements which emphasize the discretion of the program manager:

> While it is true that commonality does not require that an identical item be produced by the second source, it is permissible and within the procuring activity's discretion as to which of two technical approaches it believes will better fulfill the Government's needs.[9]
>
> Therefore, while the form, fit and function approach, as embodied in the MDAC RFP, appeared to satisfy the Government's needs at the time the RFP was issued, the complexion of the procurement changed when the possibility of licensing was presented. The lower technical risk, which would better insure delivery within the Government's 1982 schedule and allow competition between Litton and the second source for the production quantities at an earlier date, would justify the sole-source award to Litton-Canada.[10]
>
> In view of the above, we do not find that JCMPO or MDAC acted arbitrarily or capriciously toward Singer. The protest and claim are denied.[11]

While the JCMPO may not have acted arbitrarily or capriciously toward Singer, it apparently defined "need" in a manner that supported its decision rather than basing its decision on need. In fairness, the JCMPO conducted extensive analyses which indicated that the LSL option would require significantly lower start-up and logistics costs. However, the analyses were not conclusive as to whether the competition between LG&CS and LSL would have been as effective as the competition between LG&CS and SK. Thus, it is conceivable that the higher start-up and logistics costs could have been offset by greater savings from competition between LG&CS and SK.

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[9] Ibid., p. 9.
[10] Ibid., p. 10.
[11] Ibid., p. 11.

In both cruise missile cases, the establishment of second sources to provide identical items under leader company procurement was selected over the development and production of an alternative item. It is presumed that, if second sources had been anticipated at the outset of the cruise missile program, provisions would have been made concerning data rights and technical assistance which presumably would have given the government more latitude in establishing a second source to produce an identical item.

It was stated that leader-follower maximizes contractor control and, thereby, diminishes competition. The following chapter provides a discussion of the theoretical bases for competition and examines relevant empirical data. It also provides a methodology for assessing the probable life cycle cost impact of establishing second sources.

# III. THE EFFECTS OF DUAL SOURCE COMPETITION ON COST

A major reason for advocating the establishment of second sources has been the belief that the resultant dual source competition during procurement will significantly reduce total system acquisition costs by reducing the price the government pays for new hardware. This belief has not been adequately supported by either a comprehensive theory or sufficient relevant data. Therefore, this chapter provides a conceptual framework for examining the broad effects of establishing second sources on cost and analyzes available information on competition and price to determine whether a basis exists for anticipating savings as a result of dual source competition.[1]

To accomplish these objectives, several issues are addressed separately. They include:

- Identification of elements of cost possibly affected by the establishment of a second source and the implementation of dual source competition.
- Discussion of an appropriate framework for estimating and analyzing those costs.
- Specification of the anticipated effect of a second source on production costs.
- Review of relevant microeconomic theory to establish hypotheses concerning the effect of a dual source competition on price.
- Analyses of available data on competition in the procurement of weapon systems to test the hypotheses.

Example analyses of the establishment of second sources for cruise missile subsystems tie together the separate issues and illustrate the

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[1]A distinction is made here between cost and price, as cost represents the value of the resources employed by a firm to produce an item while price represents the amount it receives for its sale. Price is generally cost plus a profit or a loss. The government's "cost" for an item is the "price" received by the producer.

anticipated effect of establishing second sources on particular cost elements.

Although the primary reason specified for establishing second sources is the expectation of cost savings from competition, it may be desirable to establish second sources even in cases where they are expected to cost more because of other potential benefits which may include reducing risks, increasing the mobilization base, and enhancing operational capabilities. The following chapter considers these issues.

## CONCEPTUAL FRAMEWORK AND METHODOLOGY FOR COST ANALYSIS

A cost analysis must be made to assess the probability, magnitude, and time phasing of added costs or savings which may result from the establishment of a second source and the implementation of dual source competition. The first step in the cost analysis is to identify all categories and elements of cost which might be affected by the alternatives being considered. Costs for a weapon system may be divided into three categories, each representing a distinct phase of its life cycle. They are:

- *Research, Development, Test and Evaluation (RDT&E) Costs* represent all resources required to develop a new system to a point where it may be manufactured in quantity at acceptable levels of reliability and performance.
- *Investment Costs* are one-time expenditures required to introduce a new system into the inventory. They include nonrecurring investment costs, which are incurred for items such as facilities and capital equipment required to produce an end item, and recurring production costs, which reflect the cost of producing the individual end items.
- *Operation and Support (O&S) Costs* are incurred to operate, support, and maintain a system from the time it reaches its initial service destination until it is retired.[2]

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[2]Since second sources usually would be established at the subsystem or component level, only support costs normally would be estimated because operational costs apply to the total system (e.g., flight crews operate an aircraft) and it is inappropriate to allocate them to the

There are several elements of cost within each life cycle cost (LCC) category. In some cases, the second source types being considered might affect the same elements differently, might affect different elements, and/or they might have the same effect on several elements. Thus, it is necessary to begin by defining a comprehensive life cycle cost breakdown structure (LCCBS) which represents all relevant cost elements.[3] In making tradeoff studies, cost elements that are unaffected by any of the alternatives or those that are affected the same by alternative types of second sources may be eliminated so that only "decision costs," or those future costs which will be affected differently by the alternatives, are analyzed.

Next, it is necessary to estimate the costs associated with each element of life cycle cost for each alternative second source being considered and to assess the effects of establishing them and of implementing dual source competition on cost.[4] The current state-of-the-art in cost estimating methodology enables relatively accurate cost estimates to be made for all cost elements except for recurring production costs as a function of two competing production sources. Because adequate data and theory are not available to support them, estimates for recurring production costs would be speculative for two firms involved in dual source competition. The methodological framework provided here requires an initial estimate of all relevant cost elements, except recurring production, and then a judgment by the decisionmaker concerning the likelihood of achieving sufficient competitive savings during the recurring production phase to offset

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component subsystems (e.g., airframe, engine, and avionics). Many decisionmakers who have been taught that O&S costs comprise the largest share of LCC are surprised to find that O&S estimates at the subsystem level are relatively small since they correctly omit operation of the complete system.

[3]A LCCBS provides a format for analyzing costs and relationships between costs and different characteristics of the alternatives being considered.

[4]In performing any cost analysis it is essential to have a valid cost estimating model, and/or relevant data and an approach for treating them so that they may be used to develop cost estimating relationships. General cost estimating techniques and potential sources of data for estimating the cost of elements which are likely to be affected by the establishment of a second source are discussed in Appendix B.

additional costs related to establishing second sources and to support the items they produce.

The following sections examine relevant economic theory and available data so that the decisionmaker may make an informed judgment regarding the effects of two producers on recurring production costs and dual source competition on price. The LCCBS developed to evaluate second source alteratives for cruise missile subsystems is presented together with actual case histories at the conclusion of this chapter.

## ECONOMIC THEORY

As mentioned above, the greatest problem in the analyses of costs related to alternative second source types is the considerable uncertainty concerning the effect of constrained competition on recurring production costs. Interestingly, this is an area where a great body of economic theory has been developed. While these theories cannot "solve the problem," they nevertheless provide a useful perspective.

The following discussion is divided into two parts. The first assesses the cost implications of splitting production between two sources without implementing competition. The second examines microeconomic theories related to competition. Significant points are then considered together to determine whether any reasonable hypotheses may be made regarding the effect of two competing production sources on the price of weapon systems.

### Production by Two Manufacturers

Before considering the effect of competition on price, it is essential to understand the recurring production cost implications of dividing a fixed quantity between two manufacturers. Three assumptions are made which are consistent with dual source procurement as described above:

- The items produced by the two manufacturers may be either identical or meet the same form, fit, and function specifications.

- The annual quantity procured by the government is inelastic.
- The high cost source would produce an annual quantity sufficient for it to maintain a viable production capability.[5]

It is hypothesized that, if competition were not a factor, dividing a fixed production quantity between two firms would cause recurring production costs to increase because of one or more of the following reasons: potential economies of scale would be lost,[6] excess capacity would be required, fixed indirect costs would be spread over a smaller base, and the learning curve would be split. Each of these reasons is discussed separately below as they could occur independently. Nevertheless, they often are interrelated.

*Economies of Scale.* Generally, cost is not proportional to quantity since most firms experience a decrease in long run average cost as output and scale of plant increase. This happens for two primary reasons. The first is that the labor force may be specialized to a greater degree as size increases, thereby improving efficiency and reducing cost. This results from eliminating the need to change tools frequently and from shortcuts which are learned by performing the same task repeatedly. Small plants, on the other hand. are often characterized by workers who perform several different tasks. Also, it becomes more cost/effective to make technological improvements as plant scale and output are increased. Nevertheless, the hand labor required to produce two of an object is generally twice that required to produce one (excluding the effect of learning which is discussed below). Thus, by dividing a requirement between two producers, opportunities to realize economies of scale by increasing the specialization of labor and by making technological improvements are forgone. In addition, material prices may be higher as volume discounts may be forgone.

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[5]This quantity has been set (rather arbitrarily) at 30 percent of the annual buy for most cases.

[6]It is recognized that, beyond some upper limit, diseconomies of scale sometimes occur. However, it is not anticipated that weapon systems would be produced in such great quantities.

*Excess Capacity.* For two firms to compete annually, it is essential that their combined capacity exceed the required quantity. Otherwise, each would be given an order to produce at full capacity to meet the government's demand. For example, if the winner were to receive as much as 70 percent of the annual quantity, then 140 percent production capacity would be required so that each firm could win the maximum quantity to be awarded. Plants of greater than optimal size for a given production quantity are by definition inefficient to some extent, as their resources are not fully utilized.

*Fixed Indirect Costs.* Total recurring production cost is comprised of direct and indirect (overhead) costs. A direct cost is any cost which can be identified with a particular objective (e.g., a contract). An indirect cost is incurred for common or joint objectives and, therefore, cannot be identified with a particular objective, but rather is allocated to all of a plant's output by means of an overhead rate. An overhead rate is computed by dividing indirect costs by some base (usually, direct labor hours or dollars) which reflects its activity.[7] Indirect costs are both fixed (rent and depreciation, for example) and variable (management salaries, for example).

If a sole source loses part of its business to a second source, its fixed indirect costs might cause its overhead rate to increase, thereby increasing the total cost of its product. Of course, the argument could be made that the second source would reduce its overhead rate by virtue of its fixed indirect costs being spread over a larger business base. However, this occurrence is not often observed.

*Learning.* "Learning" is a phenomenon which has been observed for many years and its existence has been verified by controlled tests and empirical data. Because of learning, the cost of each succeeding item is reduced.[8] Learning results from a variety of factors over the course

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[7]A complete discussion and analysis of indirect costs is provided in O. B. Martinson, Jr., *A Standard Classification System for the Indirect Costs of Defense Contractors in the Aircraft Industry*, USGPO, 1969.

[8]Learning curve theory holds that, as the total quantity of units successively produced doubles, the cost required to produce the last unit will be reduced by a constant percentage. The complement of this constant percentage of reduction is referred to as the "slope" and

of production, such as more effective manufacturing processes, improvements made to the work flow, and the familiarity of laborers with their functions.

The reduction of cost as a result of learning can be predicted through the use of "learning," "progress," "experience," or "improvement" (the terms are synonymous) curves. When two firms share the production of a fixed quantity, the potential impact of learning is not fully realized. For example, if a single firm operating on an 80 percent learning curve could produce 200 units for a cumulative average cost of $1000, then it would cost twice that for two firms to share equally the production of 400 units. However, the single firm could produce 400 units at a cumulative average cost of $800 by increasing its production. The total cost would be $80,000 (400 x 1000 less 400 x 800) greater for two firms because potential learning would not be realized.

A certain amount of learning is usually transmitted to a second source via a data package and technical assistance. Thus, the intercept (i.e., cost of its first unit) for the second source is often below that of the initial source and its slope is shallower. This would result in a lower two source cost than that indicated in the example, although it would still remain higher than the projected sole source cost.

*Conclusion.* The degree to which the factors discussed above would affect cost is speculative and would vary by industry or situation. Arguments could be made as to why each of these factors would not apply to a particular case. If the procurement were small relative to the firm's business base, the effect on economies of scale and fixed overhead might be insignificant. Or, excess capacity might exist anyway as a matter of performing other business and competing in the larger market place. And, the product could be sufficiently standardized so that neither firm would experience significant learning[9] in the future. At best, these arguments support the contention that there would be no additional cost for having two producers. It would take very special assumptions indeed to argue that two producers would achieve a savings . . . if they did not compete.

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represents the ratio of the cost of any unit and the cost at twice that unit.

[9]It has been observed that learning curves often "flatten out" after a large quantity is produced and further savings are not realized.

## Microeconomic Analysis of Markets

Fundamental considerations such as those discussed above are frequently ignored because of the strong attraction of competition which has caused it to be embraced by many legislators and policymakers as a panacea for rising weapon system acquisition costs and cost overruns. Reduced costs have resulted in many cases from establishing competition. However, it has been inferred wrongly by some that savings will always result from competition between two or more firms. This clearly is not the case.

The government's procurement cost is the price charged by the manufacturer. Over the long run the price charged by the manufacturer must recover all costs plus a profit to avoid bankruptcy and to provide an incentive to remain in business. The manufacturer may reduce its price by lowering its costs through achieving production efficiencies (using less capital, labor, or material to produce a given output), or by reducing profit. Competition has been shown to motivate both of these results. It should be noted, however, that defense industry profits are not abnormally high[10] and that reducing them below some reasonable level might have the undesirable effect of diminishing the size of the defense industrial base by driving away marginal producers. Therefore, reducing the government's cost to the lowest possible level might prove to have long term detrimental results.

Since classical microeconomic theory rarely represents the real world, it may seem superfluous to consider it in the analysis of an actual policy problem. However, the presentation of relevant microeconomic theories accomplishes several important functions as it: makes possible the specification of the best and worst theoretical cases and, thereby, limits the problem; serves as a point of departure for examining relevant empirical data; provides a framework for understanding how the systems acquisition process works; reveals some of the factors which motivate businessmen when they make price/quantity decisions.

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[10]See, for example, Comptroller General of the United States, *Defense Industry Profit Study*, USGAO, B-159896, March 17, 1971, which indicates that average defense industry profit is below 5.5 percent of sales and that, for almost all measures, defense contractors experienced lower profits for government business than for commercial business.

*Perfect Competition and Monopoly.* Some basic microeconomic concepts are introduced here to give a background for understanding the usual market for weapon systems and how it would be changed by the implementation of dual source competition. A market consists of one or more buyers and sellers. In markets with many buyers and sellers, equilibrium prices are achieved when the quantity of a good demanded equals the quantity supplied. The lowest price equilibrium would be achieved by perfect competition and the highest by a monopoly.

Perfect competition exists when there are many sellers offering standard products such that none can affect the price. The seller makes decisions only concerning the quantity it will produce and the mix of inputs it will employ. A perfectly competitive market brings about the lowest possible price because profit[11] is eliminated when the market reaches equilibrium and because the most efficient mix of factors is used to bring about the equilibrium.

Monopoly (a market in which there is but one seller for a product which has no close substitutes) is the antithesis of perfect competition. A monopolist faces the market's entire demand curve and, hence, may elect either to produce a particular quantity and sell it for the corresponding price or to establish a price and produce the corresponding quantity.

Figure 3.1 is presented to illustrate how price/quantity equilibria might differ between perfectly competitive and monopolistic markets for cruise missiles.[12] This is not a real world example. Nonetheless, it represents the extreme economic solutions for a not unreasonable set of assumptions concerning cost and demand. As shown, 2600 or 6000 cruise missiles would be produced for a unit price of $1.6M or $640K, respectively. Whether the government actually would be able to procure

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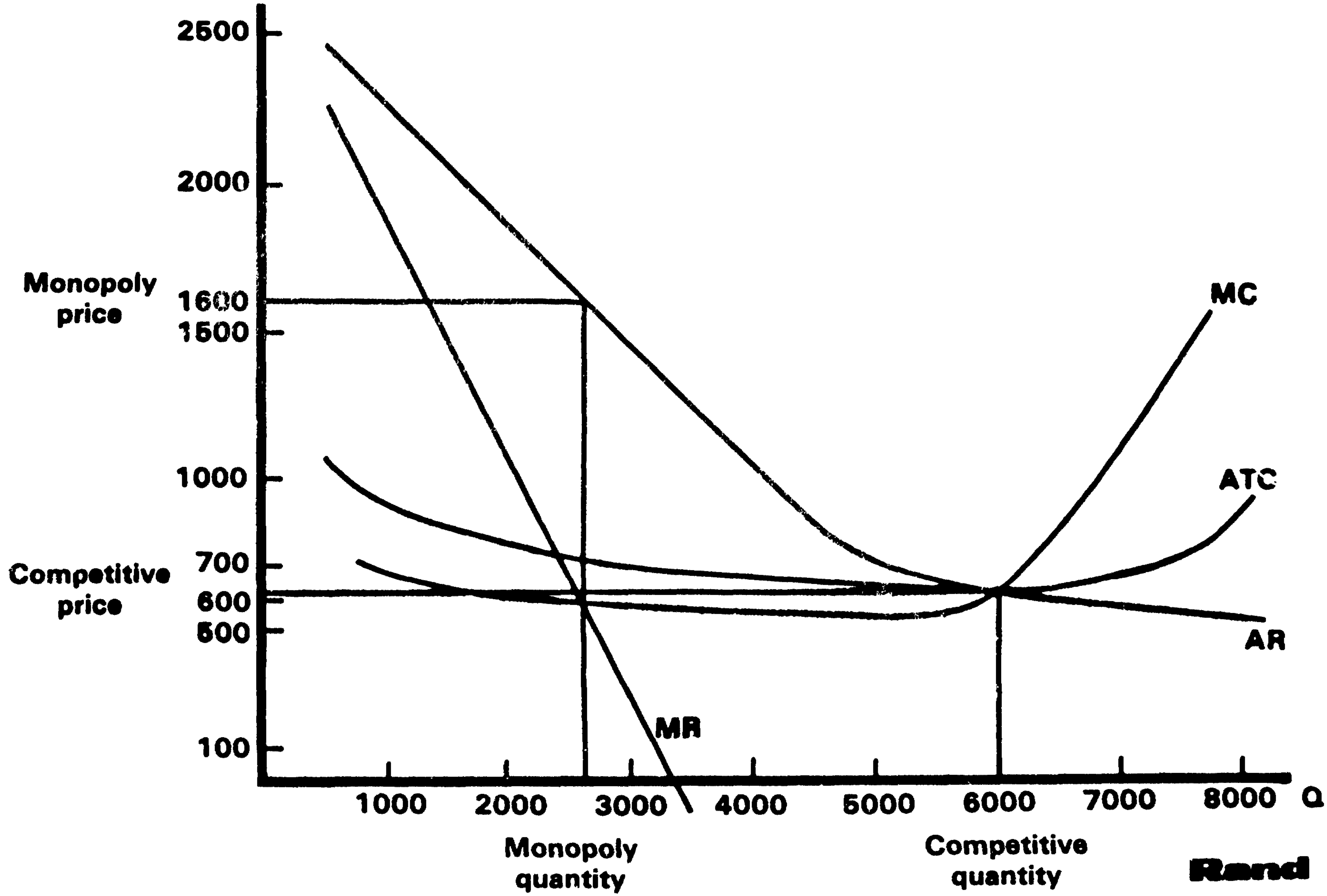
[11]Profit, as used here, is defined as the difference between costs and revenue. Since a "normal rate of return" is included as part of cost, profit is a pure surplus and its existence will attract new firms into the market until it is reduced by competition to the point where an equilibrium results in which no further firms enter or leave the market.

[12]For a complete explanation of the curves indicated, a text such as Richard S. Eckhaus, *Basic Economics*, Little, Brown and Company, 1972, may be consulted.

Figure 3.1

# EXAMPLE CRUISE MISSILE COSTS AND QUANTITIES UNDER PERFECT COMPETITION AND MONOPOLY



cruise missiles at a price and quantity near the perfectly competitive solution would depend on the utilization of its leverage as a single buyer (a monopsonist) and on the effect of establishing a market with two producers (a duopoly). Bilateral monopolies and duopolies are considered below.

*Bilateral Monopoly.* In both the perfectly competitive and the monopolistic situations discussed above, the number of buyers was assumed to be large enough that they could not individually influence price. The procurement of weapon systems by the government from a sole source is a bilateral monopoly, as there are but one buyer and one seller.

Just as the monopolist faces the entire market demand curve in selling its product, the monopsonist faces the entire market supply curve in procuring its goods. Because the market power possessed by monopolists and monopsonists is such that one buyer cannot exploit a nonexistent supply function and the seller cannot exploit a nonexistent demand function, a buyer cannot behave as a monopsonist nor can a seller behave as a monopolist simultaneously. Rather, one of three situations is possible: One participant may dominate and force the other to accept its price and/or quantity decisions; they may set price and quantity by bargaining; or the market mechanism may break down.[13] The procurement of weapon systems from a sole source is an example of a monopolist bargaining with a monopsonist to reach an agreement concerning price and quantity. Since the government is only one buyer, it has the bargaining power of a monopsonist. Most weapons are, however, sufficiently unique that the seller has the bargaining power of a monopolist. Thus, we are considering a contracting industry where the buyer and seller negotiate the purchase of a product before that product exists. A contract substitutes an administrative mechanism for a market mechanism and a fee in lieu of profits forgone.[14]

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[13] James H. Henderson and Richard E. Quandt, *Microeconomic Theory: a Mathematical Approach*, McGraw-Hill Book Company, 1971, p. 244.

[14] Merion J. Peck and Frederick M. Scherer, *The Weapons Acquisition Process, an Economic Analysis*, Harvard Business School, Division of Research, 1961, pp. 55 ff.

As shown in Figure 3.1, the price and quantity of cruise missiles are bounded by the monopoly and the perfectly competitive market solutions. However, because an actual case would involve a bilateral monopoly, it is reasonable to assume that an agreement would be negotiated for a quantity of cruise missiles at a price within the bounds of the ATC and AR curves: The government could obtain a desired quantity of cruise missiles at a price below its demand curve and the contractor could make a profit by selling at a price above its average total cost curve. The location of the point of intersection would depend upon the relative negotiating strengths and abilities of each party.

*Duopoly.* A duopoly consists of two sellers.[15] As with perfectly competitive firms and monopolies, duopolists seek to maximize profit. Unlike the other two cases, however, there are no rules governing how duopolists should behave to establish an equilibrium. Nevertheless, it is recognized that duopolists take into account the effect they have on the profit of the industry and on that of their rival. Basically, duopolists may increase their profits by jointly behaving as a monopoly and maximizing total industry profit or by capturing a greater portion of industry profit.[16]

Specific theories concerning the behavior of duopolists have been proposed since Augustin Cournot examined the case of two producers of mineral water in 1838. Other cases posed by Edgeworth and Chamberlin, for example, also offer insights as to how duopolists might behave in certain situations. However, perhaps the most useful analysis for understanding dual source competition was formulated by Stackelberg based on leadership and followership, in which the follower adjusts its output to maximize profit on the basis of its rival's quantity decision, when it assumes that its rival is indeed the leader. Thus, given two

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[15]A duopoly is a special type of oligopoly (a situation in which there exists more than one seller but still few enough sellers that the contribution of each influences the market). Theories concerning duopolies have general application to all oligopolies because the fundamental problem in each is the same.

[16]C. E. Ferguson and J. P. Gould, *Microeconomic Theory*, Richard D. Irwin, Inc., 1975, p. 330.

firms, A and B, four outcomes are possible: A desires to be leader and B the follower; B desires to be leader and A the follower; both desire to be leaders; or, both desire to be followers. Only the third outcome (a Stackelberg disequilibrium) will result in economic warfare and equilibrium will be achieved only when one firm has succumbed to the leadership of the other or a collusive agreement has been reached.[17]

*Duopoly and Weapon System Acquisition.* With a bilateral monopoly, an agreement regarding price and quantity is negotiated which is acceptable to both parties. The key issue to be considered is how this would be changed by adding a rival for the seller. Duopolists may maximize total profits by colluding and acting as a monopolist or by seeking to maximize profit for their own share of the market.

If they seek to maximize profits by capturing most of the market or by setting a high price for the residual portion, one firm will become the leader and the other the follower. Of the four possible leader/follower combinations discussed above, competition will be assured only when both firms seek to become the leader,[18] as both will then seek to capture a larger share of the market by bidding down the price.

Rivalry will exist when both firms are able and willing to compete with each other. Ability to compete generally would depend upon the second source's ability to produce at a cost as low as that of the initial source. Typically, a second source would be under a handicap because it would be behind the initial source in terms of learning and, if it uses the design prepared by the initial source, it might be required to pay royalties to the initial firm. On the other hand, if the second source uses a different design or develops more efficient manufacturing processes, it is conceivable that it could sell its product for a price the initial source could not meet. Even if firms are able to compete, they may be unwilling to do so, since they may believe that profits could best be maximized by collusion or simply by accepting the role of follower and charging a higher price for the residual quantity.

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[17] Henderson and Quandt, *Microeconomic Theory*, p. 229.

[18] This is the economic analog to Woody Hayes' statement that, when you pass the football, three things can happen and two of them are bad.

Numerous hypothetical examples may be prepared to examine the effect of dual source competition on a major defense system acquisition such as the cruise missile, depending upon the actions of the firms involved over time. The critical issues are whether the second source achieves costs lower, greater, or equal to those of the initial source during the initial competition and how this evolves over time.[19]

The a priori expectation would be for competition to be most effective for the initial buy, when both sources would be relatively uninformed about their rival's capabilities. If one proved to be significantly more efficient than the other, it is likely that they would accept their respective roles as leader and follower and implement a strategy to optimize profits over subsequent competitions. Thus, it would be essential for the government to exercise its monopsonist power by limiting profits for the firm receiving the smaller portion of the annual buy or threatening to give an entire award to the low bidder.

A major related issue is the degree to which the item involved in the competition is specialized to the extent that it is limited exclusively to the defen market where the government is the only buyer. Using the cruise missile as an example, this situation would apply to the airframe, but would be less true for the radar altimeter and engine which may have broader defense and commercial applications. It would not apply to the RMUC which is approximately 80 percent common to systems now in operation in numerous other military and commercial aircraft. Therefore, it should be determined whether a particular military procurement represents the only application or but one of several markets available for an item and how that finding might affect dual source competition. It seems likely that two firms regularly facing each other in competition with similar products would be more prone to vie for the position of leadership. The very fact that they are in competition over the long term presents prima facie evidence that

[19]Economic markets are normally characterized by the interchange of complete information, which leads to the immediate adjustment of prices based on the information received. The defense market is significantly different, however, in that there is no immediate flow of information to enable bidding. Thus, firms cannot respond to their rivals' actions until a subsequent buy, which generally takes place annually.

their costs are similar and, since their products have broader applicability, it is expected that the second firm would not incur a major learning penalty.

In other words, it is expected that dual source competition would be most effective when the firms involved regard it as part of an ongoing rivalry in a particular area. Dual source competition would not be expected to be as effective if the product involved was highly specialized and the firms were not traditional rivals. Thus, the total potential cost to the government resulting from a split-buy could be significantly higher than for a sole source procurement or it could approach that of a winner-take-all competition. However, it would require an exceptional case to argue that the potential cost to the government would be lower when the buy is split than when periodic, winner-take-all competitions are held.

## Summary

At the outset, it was hypothesized that two producers would be less efficient than one for several reasons: Potential economies of scale would not be realized; excess plant capacity would be required; fixed costs would be spread over a smaller base; and the learning curve would be split. Despite these adverse conditions, the nature of the rivalry which would result from dual source competition was examined to determine whether it could result in a lower cost to the government.

It was determined that, since defense procurement is typically a bilateral monopoly, the cost paid by the government would be established by negotiation but would be somewhere between its demand curve and the seller's average total cost curve. The cost actually negotiated would depend upon a number of factors, among them the skill of the negotiators and the alternatives they have (e.g., the availability of substitutes). Certain long term considerations also probably would be factors. For example, a low price which ultimately would result in a loss to the seller also might be detrimental to the government in the long term, since it could shrink the size of the defense industrial base. Additionally, the exploitation of its monopolist power might cause the seller to be regarded unfavorably in a future procurement. Thus, negotiated costs and profits tend toward the "reasonable" range.

The government's objective in creating dual source competition is the reduction of price to a lower stratum of the reasonable range than would occur without competition. Whether the total cost would be reduced when the government buys from two sources would depend on how low the sole source price was initially and on the willingness and ability of the two firms to compete. Whether the second source would be willing and able to compete with the initial source must be determined on a case by case basis. It would, however, make little sense (based on cost considerations alone) to establish a second source when the sole source was perceived as being efficient and the contract already within the lower band of the reasonable range. This would be especially true if there were no ready candidates and one would have to be created by incurring large start-up costs for R&D or technology transfer, and facilities, equipment and tooling.

## STUDIES ON COMPETITION IN WEAPON SYSTEMS ACQUISITION

As shown above, there is no coherent theoretical reason to assume that a duopoly/monopsony market will result consistently in a lower price than the bilateral monopoly which generally characterizes the acquisition of major weapon systems. Nevertheless, it was important to determine whether actual experience would provide lessons which might be useful in understanding the effects of competition in the acquisition of weapon systems.

Since the early 1970s, several studies have attempted to assess the effects of competition on the acquisition of weapon systems. Many of these studies were obtained and reviewed and a cross section of them is discussed below to document the evolution of this research and to note important findings.

Key studies were performed by the Institute for Defense Analysis (IDA),[20] ARINC,[21] and the Army Procurement Research Office (APRO)[22] with

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[20]Zusman et al., *Competition During Procurement*. (Subsequently referred to as 1974 IDA Report.)

[21]John D. Neate and Malcolm A. Burgess, *Assessment of Historical Cost Data Regarding the Effects of Competition on DoD/Military Procurement Costs*, ARINC Research Corporation, Publication 6411-1555, November 1976. (Subsequently referred to as ARINC Report.)

[22]Edward T. Lovett and Monte G. Norton, *Determining and Forecasting*

the assistance of Tecolote Research, Inc. (TRI).[23] Other studies, more limited in their scope, have served to augment and interpret the findings of these studies and to define their limitations. Significant findings of these studies are summarized below and their methodologies are discussed. It is important to note that there are inherent factors in these studies which limit their applicability to the analysis of dual source competition. These limiting factors include:

- Most of the competitions were winner-take-all.
- Many of the competitions were open to several competitors and R&D or technology transfer was only rarely required to establish competition.
- There was no evidence of competition between different items of identical form, fit, and function.
- Since competition was established at the discretion of the program manager, it may have been implemented only for cases where the program manager was not satisfied with the performance of the initial source. Thus, there is reason to assume that a systematic bias exists in the data reported and that different results would have been obtained if competition had been implemented either for all programs or randomly.

## The 1974 IDA Study

Early in 1974, IDA published a study performed under contract from the Advanced Research Projects Agency.[24] It covered three separate issues: cost-quantity relationships, competition during procurement, and military vs. commercial prices. The data initially gathered by IDA on competition during reprocurement served as the basis for other reports on competition in the procurement of weapon systems.[25] The

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*Savings from Competing Previously Sole Source/Noncompetitive Contracts*, U.S. Army Procurement Research Office, APRO 709, U.S. Army Logistics Management Center, Fort Lee, Va., October 1978. (Subsequently referred to as APRO Report.)

[23]Arthur J. Kluge and Richard R. Liebermann, *Analysis of Competitive Procurements*, Tecolote Research, Inc., TM-93, Santa Barbara, Ca., August 1978.

[24]1974 IDA Report.

[25]Larry Yuspeh, *The General Advantages of Competitive Procurement*

objective of the part of the IDA study which dealt with competition was to examine quantitatively the effect of competition on selling price and IDA reported the following principal findings:

- First,

> Significant savings were realized on the first competitive award when competition was introduced during the reprocurement phase of selected programs. For the 20 cases in the data base, the average savings were 37 percent.[26] The amount of the savings was directly correlated with the sole-source progress-curve slope and the type of competition. The flatter the sole-source progress curve the greater the saving observed was likely to be. With respect to type of competition, a winner-take-all competition resulted on average in a greater percentage of savings being observed than a competition in which the competitors were competing for a share of the total award rather than the whole award. However, the effect of a winner-take-all competition on the course of future competitions could not be determined from the available data.

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*over Sole Source Negotiation in the Defense Department*, prepared for the Subcommittee of Priorities and Economy in Government of the Joint Economic Committee, Congress of the United States, November 12, 1973; and Gregory A. Carter, *Directed Licensing: An Evaluation of a Proposed Technique for Reducing the Procurement Cost of Aircraft*, The Rand Corporation, R-1604-PR, December 1974.

[26]IDA's findings were based upon the analysis of data it collected which were subject to the following criteria: Price data had to be retrievable; at least two sole source production awards had to be made so that a sole source learning curve could be established; at least one competitive award had to be made; and the unit cost had to be at least $1,000 to avoid consideration of inconsequential items.

Using its assembled data, IDA estimated the percentage savings for the first competitive buy by estimating the sole source cost without competition, based upon an extrapolation of its established learning curve for that lot and dividing the estimated cost less the actual cost by the estimated cost:

Percent Savings = E - A/E x 100

Where: E = Estimated cost of buying the completed units by an extension of the sole source learning curve;
A = Actual cost of the first competitive award.

- Second,

> The post-competitive progress curve is characterized by a lower intercept (first-unit cost) and a flatter slope than the sole-source progress curve. This means that the gross savings (from what would be expected to be paid if the sole-source progress curve were extrapolated), measured in percentage terms, will decline for each succeeding competitive award.[27]

In addition to these primary findings, IDA offered several interesting explanations for observations it made about the data it collected. IDA offered the following explanation for the observation that the learning curve generally became flatter following competition:[28]

> On the one hand, during the sole-source procurement, DoD forces the sole-source producer to lower his price as he proceeds down the cost-progress curve. On the other hand, in a competitive procurement (where the emphasis is on price rather than on cost), the competitive producer has an incentive to establish a price that is sufficiently low to capture the market. However, once the market is captured, he has no further incentive or DoD requirement to lower the price more than necessary to maintain the market, regardless of how his costs decline. In the case of the limited market for specialized DoD products, where there is a winner-take-all competition, there is little incentive for the winner of the first competitive award to lower his price significantly on the second competition, since he knows that none of the losing competitors of the first competition were able to lower their costs through the progress-curve phenomenon; and, hence, the losers' second-round competitive bids are not likely to be much lower than their first-round competitive bids. The flatter competitive price-curve is quite consistent with what is sometimes observed for certain products (particularly vehicles) in the commercial (competitive) marketplace, where the product prices follow an essentially flat price-quantity curve over relatively large production quantities.

This phenomenon indicates that the two progress curves would cross at some point, whereupon the sole source would again exhibit the lower unit cost. Although this would occur at a point well beyond normal buy

[27] 1974 IDA Report, Vol. 2, pp. 1-2.
[28] Ibid., p. 66.

quantities, it would cause total competitive savings to be less than the percentage estimated for the first lot.

One of the most interesting findings in this study is that the initial source won only one of the 17 winner-take-all competitions documented. The explanation provided by IDA is astute: ASPR (now DAR) guidelines for establishing profit objectives are weighted in favor of various factors of production. Thus, engineering labor generates greater profit than manufacturing labor which in turn generates greater profit than material. Since businesses seek to maximize profit, the management of a sole source stresses the use of labor over capital in producing the product even when so doing sacrifices efficiency. When a competition is held, a fixed price contract usually is awarded to the winner. This type of contract rewards efficiency as all revenue in excess of cost is profit. There fore, the new competitor's bid is based on the most efficient method of production possible while the initial source is more or less locked into his existing, inefficient methods.[29]

The objective of the 1974 IDA study was to assess the effect of competition throughout a product's life. However, the available data limited the analysis to the reprocurement phase alone. One cost directly related to competition was cited in the study in terms of an example: The Bullpup missile competition resulted in a nose cone which was redesigned to reduce the price. Nevertheless, problems with the new design eventually caused Bullpups using it to be grounded until a fix could be made (at the government's expense).[30] Data problems related to costs outside the reprocurement phase notwithstanding, the failure of this study to identify other cost elements which might be affected by competition and, then, to treat them even qualitatively is its greatest shortcoming because, as subsequent studies showed, savings in the reprocurement phase may be offset by nonrecurring costs associated with its implementation.

[29] Ibid., pp. F-1 ff.
[30] Ibid., p. 53.

Data collected by IDA have been used as the basis for other studies related to competition in the defense system acquisition process. A study by Yuspeh[31] which has been widely disseminated does not acknowledge the 1974 IDA study as the primary source and, therefore, has been frequently cited as a primary data source. Data from the Yuspeh study were used by Carter in the study he conducted ". . . to evaluate the feasibility of introducing price competition into the procurement of major weapon systems by means of a technique known as 'directed licensing.'"[32] Carter noted several errors in the Yuspeh study which were not present in the 1974 IDA study, as well as a significant problem in the Yuspeh study which also exists in the 1974 IDA study: Both used contract prices rather than final prices which were adjusted to reflect other costs such as claims.

## STUDIES RECOGNIZING THE NEED FOR A BROADER PERSPECTIVE

After the studies discussed above were released and reviewed, many analysts recognized that their relatively narrow focus of looking only at contract costs for recurring production resulted in misleading conclusions and several briefings, memos, and short-term studies addressed this issue. The point made by Carter concerning claims was bolstered substantially by Terry Rucker in an unpublished briefing.[33]

Rucker examined six competitive tactical missile procurements held during the 1960s which were won by a second source. Four of them resulted in claims being filed by the second source which ranged from \$4.2M to \$40.0M (the government paid settlements ranging from \$2.5M to \$22M). In another case, a second source incurred a \$16M overrun, which it did not claim. In the final case, the government was required to pay engineers from the initial source to solve problems experienced by the second source. When these added costs are considered, estimated savings diminish significantly.

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[31] *Advantages of Competitive Procurement*.
[32] *Directed Licensing*, pp. 2-3.
[33] Untitled notes on competition, NAVAIR, December 1977.

The frequency with which claims are made and won demonstrates another advantage second sources enjoy in a competition based upon a data package prepared by another source: Since data packages are usually deficient to some degree, the second source has built-in insurance against cost overruns--if it bids too low and faces a probable loss, it can claim that the data package was inadequate. Obviously, the initial source is precluded from taking such an action.

Rucker also noted that many of the data which indicated substantial savings as a result of competition were based on quantities procured during the Viet Nam era which were much greater than current procurement levels. For example, annual buy quantities for four missiles in procurement during the mid-1960s to mid-1970s decreased by about 40 to 70 percent in the post-war period. Rucker stated that current quantities are insufficient to amortize nonrecurring costs required to qualify a second source to compete with the initial source.

Another Navy cost analyst examined the Sidewinder AIM-9B seeker assembly procurement to determine if any cost savings resulted from competition.[34] Although savings of about 21 percent were indicated based upon the first winner-take-all competition, the savings were reduced to about eight percent when the higher initial recurring production costs resulting from the preceding split-buy competitions were considered. Furthermore, it was noted that, if the nonrecurring start-up costs for the second source were included, the net savings resulting from the competition would be insignificant.

ARINC conducted a study on the effects of competition on military procurement costs to help form the basis for making decisions concerning U.S. Air Force procurement strategies for the Advanced Landing System (ALS).[35] In performing this study, it reviewed several reports on competition in reprocurement and collected supplemental raw data. Like other studies discussed above, it estimated the sole source price by extrapolating its established learning curve. The ARINC study concluded

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[34]Frank Carroll, *Competitive Aspects of the AIM-9B Seeker Assembly Procurement*, memorandum to Carl Wilbourn, U.S. Navy OP-96D, December 16, 1977.

[35]ARINC Report, p. 1.

that a significant acquisition cost saving might be realized by the introduction of competition:

> . . . an average acquisition cost saving of 38 to 44 percent for systems of the same order of complexity and technology as the ALS can result directly from the introduction of competition if a sole-source procurement is selected for competitive reprocurement.. . .[36]

However, it made one important caveat:

> A sole-source procurement that is being kept "on track" by an innovative, well-motivated contractor with a steep learning curve may not be affected by the introduction of a competitive reprocurement.[37]

It also recognized that, because data were limited to acquisition cost, conclusions could not be made regarding the overall cost of ownership (LCC) of the reprocured systems.

Thus, after the initial feeling that competition might be a panacea for high procurement costs, it was realized that data limited to procurement contract price alone were perhaps very misleading.

## The APRO Study

In late 1978, the Army Procurement Research Office (APRO) published a study on determining and forecasting savings from competing previously sole-source contracts.[38] APRO was assisted in the collection of data and in the development of analytical methodology by Tecolote Research, Inc. (TRI).

APRO recognized that failure to understand how competition in fluenced procurement price hindered defense decision making:

> Within the defense market, it is difficult to isolate, identify, and quantify the impact of competition on acquisition costs. Traditionally, a 25% reduction is

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[36] Ibid., p. 10.
[37] Ibid.
[38] APRO Report.

> expected, but there is no empirical support for such expectation. Actually the Department of Defense has no firm basis for deciding when to introduce competition or even if competition should be introduced. When the value of competition cannot be measured with a reasonable degree of confidence, defense of budgetary estimates and the development of a good acquisition strategy is exceedingly difficult, if not impossible.[39]

Thus, the study sought to: develop a methodology to estimate the net savings achieved due to competition; develop a methodology to estimate the savings from introducing competition into future weapon systems; and provide an organized data base to support the methodologies.

The study arrived at the following conclusions:

> The savings achieved by introducing competition into the production of weapons systems can be reasonably estimated. Of the sixteen items analyzed, five showed a loss due to competition. Savings for the sixteen items averaged 10.8 percent. The forecasted savings methodology (FSM), which was developed from the analysis of the sixteen systems, is a useful tool which provides an estimate of the expected savings, or loss, from introducing competition as well as an analysis of the qualitative factors influencing competition.[40]

In conducting the analyses, data were collected on 16 electronics and missile systems (ten by APRO and six by TRI) which were initially produced by a sole source and later competed. The data reviewed were extensive and included contract files, cost reports, audit reports, progress briefings, and interviews with informed government and contractor personnel, among others. Both quantitative and qualitative factors affecting savings due to competition were retained in the data base.

The estimated savings methodology used by APRO considered non-recurring start-up costs, learning, inflation, and discounting, as well as recurring production costs. APRO also acknowledged that additional government administrative costs may be incurred for the following

[39]Ibid., p. 1.
[40]Ibid., p. ii.

purposes in establishing competition: preparation of the solicitation, preparation of the technical data package, evaluation of offers, negotiation of an additional contract, conduct of additional pre-award and Should-Cost studies, and extra testing costs, among others. It did not attempt to quantify these costs for the cases reported.[41] Additional O&S costs were not considered.

After collecting and normalizing the data and determining the sole source learning curve, savings credits and debits were calculated and the net effect of competition was estimated. APRO determined savings credit by:

1. Calculating the pre-buy-out recurring costs;
2. Projecting the sole source learning curve for the remaining buy, as if no competition had been held;
3. Calculating the competitive price paid for the remaining buy, based on projecting the winning contractor's post-competition learning curve;
4. Subtracting the projected competitive price from the projected non-competitive price (item 2 less item 3, from above).

APRO determined savings debits, which were defined as costs incurred by the government solely because of competition, including: unrecouped progress payments from a contractor who went bankrupt trying to produce an item; all nonhardware and nonrecurring prices for the second source; payments to the sole source contractor for support of the second source; and costs related to program stretch-out caused by adding a second source. Debits were subtracted from credits to determine the total savings which resulted from competition. Percent savings were calculated by dividing the total savings by the total estimated sole source program cost.

The main problem with this part of the study is the basis used to calculate the savings resulting from competition. When all sole source production (sunk) costs are included and percent savings figured over the total production program, estimated savings become extremely sensitive to the point in production at which competition was

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[41] Ibid., p. 90.

introduced. Although such a procedure is not incorrect from a historical standpoint, it can be misleading with respect to the potential impact of competition.

APRO recognized that, although competition offers significant potential benefits, there are also risks involved: Five of the 16 cases it analyzed "lost money" as a result of competition. It also noted other risks, including: potential degradation of relations with the system developer; unreasonably low bids, due to either a buy-in or an inexperienced contractor; an inadequate data package which might lead to claims against the government; and reduced quality resulting from cost cutting.

APRO also developed a three-part methodology for forecasting the savings which will result from establishing competition in a sole source procurement. The methodology includes: a checklist of criteria which should be met before considering a competition; an equation estimating the savings from a competition; and an index for evaluating qualitative factors related to competition.

The equation included in the forecasting methodology estimates the price of a competitive procurement based upon the projected unit price of a sole source procurement and the ratio of the quantity to be procured in the buy-out competition to the total program quantity.[42] While the ratio of the competitive quantity to the total quantity (or a similar variable to represent the portion of the buy which will be competed) is intuitively essential, analysis of the data from which it was derived found it to be statistically insignificant. Therefore, the equation is essentially a function only of the expected sole source price. This defies logic.

APRO made significant contributions by providing comprehensive quantitative and qualitative data for the cases it analyzed and by enlarging the scope of its analyses to include elements of cost in addition to recurring production. However, it was unsuccessful in providing a valid methodology for deciding if and when to implement competition.

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[42] Ibid., p. 75.

## The 1979 IDA Study and the Rand Study

IDA[43] and The Rand Corporation[44] each published a study while this report was in various stages of preparation and review. Neither of these studies provided additional empirical data on competition; rather, both relied upon previously published data (primarily from the 1974 IDA study and the APRO study). Nonetheless, both provide some interesting and useful findings, a selection of which are discussed below.

The purpose of the 1979 IDA study was to examine costs and benefits of price competition during reprocurement and to determine: when competition should be introduced; how long multiple sources should be maintained when competition is introduced; and how to improve competition.[45]

IDA segregated the available data on competition into electronics and communications items and missiles and missile components, for which it found that savings resulting from winner-take-all competition averaged 48 and 28 percent, respectively. More important, how ever, was the observation that savings estimates were not expressed in ways which related to valid criteria for government decision making.[46] IDA, therefore, recommended that the implementation of price competition should be considered as an investment strategy and that several characteristics of a particular procurement should be useful in evaluating the probable success of a competition, including: quantity, duration of production run, and the slope of the sole source learning curve. It found that the flatter the curve, the more likely that savings would result.

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[43]George G. Daly, Howard P. Gates, and James A. Schuttinga, *The Effect of Price Competition on Weapon System Acquisition Costs*, Institute for Defense Analysis Program Analysis Division, P-1435, September 1979. (Subsequently referred to as the 1979 IDA Report.)

[44]K. A. Archibald, A. J. Harman, M. A. Hesse, J. R. Hiller, and G. K. Smith, *Factors Affecting the Use of Competition in Weapon System Acquisition*, The Rand Corporation, R-2706-DR&E, February 1981.

[45]1979 IDA Report, p. S-1.

[46]Ibid., p. S-3.

IDA's observation concerning items with flatter learning curves and the greater probability that competition would yield savings for them than for items with steeper learning curves is accurate only if an important caveat is added: The learning curve slope must be based upon the actual first unit cost. For example, when a key part of an item is primarily off-the-shelf (such as the inertial platform for the cruise missile RMUC), unit one for a particular procurement (such as the cruise missile) might be a much higher unit in terms of total production for that item. This, of course, would indicate a very flat learning curve slope as much applicable experience would be ignored.

IDA also acknowledged that non-price (qualitative) aspects of competition are important and may be the deciding factor in determining whether to implement competition. Important qualitative considerations include: "inadequate technical performance of the original producer, fear of reduced reliability or delivery delays, the impact on the [defense] industrial base, and the impact on logistics and maintenance. . . ."[47]

Finally, IDA reported that the tangible preparation for competition has often been found by procurement officers to have a beneficial effect on previously uncooperative sole sources. Of course, if the preparation itself does not yield meaningful results, at least the ground work for competition has been laid.

The Rand study considered how DoD "might stimulate more effective competition in major acquisition programs"[48] through an examination of incentives, disincentives, and uncertainties regarding competition as perceived by program managers and other senior DoD acquisition officials. It concluded "that existing research provides neither quantitative nor qualitative guidance for designing price-competitive reprocurement strategies"[49] nor any convincing evidence (with the

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[47]Ibid., p. S-6.

[48]Archibald et al., *Factors*, p. 6.

[49]Ibid., p. vii. Rand reviewed four prior studies, including the 1974 and 1979 IDA Reports, the APRO Report, and ECOM72: U.S. Army Electronics Command, Cost Analysis Division, Comptroller, The Cost Effects of Sole Source vs Competitive Procurement, February 1972.

possible exception of electronic items) of savings due to competitive reprocurement. It recommended further work on methods of forecasting and evaluating costs and benefits of various competitive strategies and suggested that, in order to accomplish this, better records should be kept for competitive acquisition actions to improve the data base and that a theory of how competition should function in weapon system acquisition should be developed.

One of the more interesting parts of the Rand study was an illustration provided in support of its observation that estimates of cost savings resulting from competition lack credibility. Using the Shillelagh missile as an example, Rand showed that estimated savings ranged from 79 percent to zero in four studies. In addition, the 1979 IDA study included six estimates of Shillelagh cost savings to illustrate the sensitivity of the estimating methodology to the slope of the sole source learning curve and to the components included in the cost. By making reasonable assumptions, the IDA estimates extended the range to -14 percent.[50]

The recent IDA and Rand studies have provided useful interpretations and analyses of findings of previous studies and of the data upon which they were based. Although neither was able to provide a methodology for determining whether, when, and how to introduce competition, both provided useful findings which enhance the understanding of this complex issue.

## Summary

The attractiveness of competition as a means of reducing recurring production costs has led to several studies which have attempted to quantify the savings resulting from previous competitions and to provide methods for estimating the savings which might result from introducing competition into specific future procurements.

The 1974 IDA study indicated average savings of about 37 percent on the first competitive award as a result of competition. The APRO study found that savings as a result of competition averaged 10.8 percent of the total procurement cost for the systems it studied. Both studies cited cases in which the establishment of competition apparently

[50]Ibid., p. 47.

resulted in higher costs than would have been incurred from a sole source procurement. Other studies cautioned that added nonrecurring costs incurred in the establishment of competition might offset recurring cost savings.

While there seems to be a general consensus that competition, appropriately applied, is an effective tool for reducing procurement costs, few of the data or analyses provided are directly relevant to dual source competitions. With few exceptions, split awards have been made only as educational buys to establish a viable second source, and form, fit, and function competitions remained undocumented.

No methodology has been provided for forecasting savings resulting from competition which has face-validity and/or merits user confidence by providing rational and consistent results. Certainly, no existing methodology attempts to deal specifically with split awards.

## ANALYSES OF EMPIRICAL DATA ON COMPETITION: RECURRING PRODUCTION COSTS

None of the studies on competition specifically addressed dual source competition. Therefore, data related to the effect of competition on price were collected from four of the studies discussed above (1974 IDA, ARINC, APRO, and TRI) and were combined into a single data base so that an independent analysis could be made. A total of 45 different items was included.[51] They are summarized in Table 3.1 together with information related to the source of the data, type of competitive procurement (some split-buy or only winner-take-all), and magnitude of the program (total quantity produced and average unit prices). The methodology followed in analyzing the available data and general problems inherent in the data are discussed below.

[51] In addition, complete data on the Sparrow AIM-7F were obtained independently from the Naval Air Systems Command and are included because of the procurement's importance as an example of dual source competition.

Table 3.1

SUMMARY OF COST/QUANTITY DATA RELATED TO
THE EFFECT OF COMPETITION ON PRICE

| Item | Source(s) of Data | | | | Type of Competition | | Production Dates | | Total Quantity Produced (000) | Average Unit Price ($72FY) (000) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1974 IDA | ARINC | APRO | TRI | Split Buy | Winner Take All | Begin | End | | |
| Bomb | | | | | | | | | | |
| Rockeye | X | | | | X | | 67 | 73 | 126.5 | 2.2 |
| Torpedoes | | | | | | | | | | |
| Mk48 (warhead) | X | | | | | X | 70 | 73 | 1.0 | 9.7 |
| Mk48 (elec. assy.) | X | | | | | X | 70 | 73 | 1.0 | 12.6 |
| Mk46 (complete) | | | | X | X | | 64 | 69 | 12.0 | 36.1 |
| Missiles | | | | | | | | | | |
| Standard (complete) | X | | | X | | X | 66 | 72 | 5.9 | 52.0 |
| Shillelagh (complete) | X | | X | | X | X | 66 | 69 | 88.2 | 3.2 |
| TOW (complete) | X | | X | | X | X | 69 | 75 | 78.5 | 3.4 |
| Hawk (motor parts) | X | | | | | X | 57 | 64 | 14.5 | 1.5 |
| Dragon | | | X | | X | | NA | NA | NA | NA |
| Missile guidance & controls | | | | | | | | | | |
| Talos | X | | | | | X | 58 | 66 | 2.1 | 163.8 |
| Walleye | | | | X | | ? | 64 | 71 | 9.3 | 9.4 |
| Bullpup | X | | | X | X | X | 58 | 64 | 45.1 | 4.0 |
| Shrike | X | | | X | X | X | 64 | 71 | 18.0 | NA |
| Sidewinder AIM-9B | | | | X | X | | 55 | 64 | 67.1 | 2.2 |
| Sidewinder AIM-9D/G | X | | | X | X | | 60 | 71 | 10.0 | 6.8 |
| Sparrow AIM-7F | | | | | X | | 72 | 80 | 9.2 | 56.2 |
| Communications | | | | | | | | | | |
| AN/SQS-208A transducer | X | | | | | X | 67 | 73 | 0.2 | 50.2 |
| TD-660 multiplexer | X | | | | | X | 67 | 69 | 3.6 | 9.1 |

Table 3.1--continued

| Item | Source(s) of Data: 1974 IDA | ARINC | APRO | TRI | Type of Competition: Split Buy | Winner Take All | Production Dates: Begin | End | Total Quantity Produced (000) | Average Unit Price ($72FY) (000) |
|---|---|---|---|---|---|---|---|---|---|---|
| AN/GRC-103 radio relay | X | X | | | | X | 66 | 69 | 1.0 | 26.9 |
| AN/GRC-106 | | X | | | | | 66 | 67 | 7.1 | 12.7 |
| WRC-1 receiver transmitter | X | | | | | X | 66 | 72 | 1.6 | NA |
| APX-72 airborne transponder | X | | | | | X | 70 | 72 | 27.5 | 3.0 |
| SPA-25 radar indicator | X | | | | | X | 64 | 72 | 2.0 | 8.9 |
| AN/UPM-98 radar test set | | X | X | | | X | Pre69 | 75 | 0.6 | NA |
| AN/ARA-63 radio receiving-decoding set | X | | | | | X | 69 | 72 | 2.4 | 6.2 |
| AN/FYC-8x | | X | | | | | 66 | 69 | 0.2 | 12.5 |
| TD-352 multiplexer | X | | | | | X | 65 | 69 | 3.7 | 7.4 |
| AN/PRC-25 | | X | | | | | 62 | 63 | 15.9 | 2.0 |
| TD-204 cable combiner | X | | | | | X | 67 | 69 | 8.7 | 3.4 |
| CV-1548 converter | X | | | | | X | 65 | 69 | 11.6 | 3.1 |
| AN/ARC-54 radio | X | X | | | | ? | 64 | 66 | 10.3 | 5.4 |
| TD-202 radio combiner | X | | | | | X | 65 | 68 | 3.7 | 3.3 |
| Mk980/PPS-5 | | X | | | | | 66 | 70 | 0.1 | 8.8 |
| Aerno 60-6042 elect. cont. amp. | X | | | | | X | 66 | 72 | 0.7 | 7.3 |
| MD-522 modulator-demodulator | X | | | | | X | 66 | 70 | 4.8 | 3.1 |
| AN/ARC-131 airborne radio | | X | X | | | | 67 | 72 or 76 | 8.3 | 3.6 |
| AN/APM-123 xponder test set | X | X | | | | X | 65 | 69 | 1.7 | 6.0 |
| AN/ASN-43 | | X | | | | | 67 | 69 | 2.3 | 2.3 |
| AN/PRC-77 manpack radio | X | X | X | | | X | 67 | 78 | 143.3 | 0.7 |
| FGC-20 teletype set | X | | | | | X | 67 | 70 | 2.0 | 2.1 |
| USM-181 telephone test set | X | | | | | X | 67 | 72 | 1.2 | 0.9 |
| AN/VRM-1 radio test set | X | | | | | X | 67 | 70 | 1.1 | 0.4 |
| Forward Area Alert Radar | | | X | | | X | 68 | 74 | NA | NA |

Table 3.1--continued

| Item | Source(s) of Data | | | | Type of Competition | | Production Dates | | Total Quantity Produced (000) | Average Unit Price ($72FY) (000) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1974 IDA | ARINC | APRO | TRI | Split Buy | Winner Take All | Begin | End | | |
| Electrical | | | | | | | | | | |
| PP-4763/GRC power supply | | X | X | | | X | 69 | 76 | 3.2 | 1.7 |
| Aerno 42-2028 generator | X | | | | | X | 67 | 70 | 1.7 | 0.6 |
| Aerno 42-0750 voltage regulator | X | | | | | X | 66 | 72 | 2.2 | 0.1 |

## Analytical Methodology and Data Limitations

The analyses presented below address the effects of dual source and winner-take-all competitions on cost. Like all analytical tools, the method for assessing the cost effects of competition is imperfect. In addition, the available data have certain limitations which may bias the findings. Therefore, it is important to review the analytical methodology used and the inherent limitations of the data to put the findings of this study into perspective and to encourage the appropriate restraint in interpreting them.

*Analytical Methodology.* The initial analytical step was to divide the available data into two groups: those for which some split-buys were held and those for which only winner-take-all competitions were held following a period of sole source production. Nine items which were obtained by a competitive split-buy at some point during their procurement were analyzed in detail to achieve both a qualitative and a quantitative understanding so that inferences could be made regarding the implications of dual source competition. Items for which only winner-take-all competitions were held were treated in summary form. They represented the "best case" for competition as they typically included relatively inexpensive items which were relatively simple from a technical/manufacturing standpoint and allowed for greater government responsibility with little or no dependence on the developer. These factors also implied that minimal start-up time was required so that an annual competition could be held without maintaining ongoing production by two sources.

Following separation of the data into two groups, all available information for each item regarding cost, quantity, type of procurement (i.e., sole source, split-buy, or winner-take-all) and year was reviewed and combined into a single table to provide a reliable and complete sample. By accomplishing this, buys which were overlooked by one source were included or buys which were based upon bids rather than actual prices were eliminated. For example, all seven cases reported in the ARINC study which were covered more thoroughly in another source were found subject to major discrepancies because buys were omitted or costs and/or quantities were incorrect. Furthermore, ARINC did not identify

the companies involved and in some cases attributed a significant savings to a competition based on bid price while ignoring the fact that no deliveries were made and that the contract ended in default. Even though such data were unusable for aggregate quantitative analyses, they often provided interesting insights as the cases reported by ARINC which ended in default provided the only information concerning the level of expected "savings" at which defaults occurred.

The generally accepted methodology for assessing the effect of competition on recurring production cost was mentioned above under the descriptions provided for the 1974 IDA and the APRO studies and is discussed in greater detail here. The main issue in measuring added costs or savings resulting from competition during recurring production is: "Compared to what?" Obviously, once competition has been introduced into a program, the recurring production cost of a sole source must be estimated rather than measured. As mentioned in the discussion of "learning" presented above, costs tend to decrease for successive units produced. Thus, if a learning curve is established by the initial source, then its cost for producing various quantities may be estimated. To establish a sole source learning curve, cost and quantity data for at least two non-competitive buys are required. To neutralize the effect of inflation so that only the effect of learning remains, costs must be converted into constant year dollars. This is accomplished by the application of inflation factors.

Once a sole source learning curve has been established, the effects of competition may be estimated. If the government's actual cost for the competitive quantities is above the cost estimated for a sole source, an added cost is assessed to competition; if its actual cost is below the estimated cost, a savings is credited to competition. This methodology is depicted in Figure 3.2. Although this methodology is relatively straightforward, significant errors may result from both the application of inflation factors and the calculation and extrapolation of the learning curve.

Economic adjustment indices measure the change in the purchasing power of the dollar over time. Inflation affects various sectors of the economy differently depending upon the factors of production they use. Thus, inflation factors developed for a broad economic sector may not be

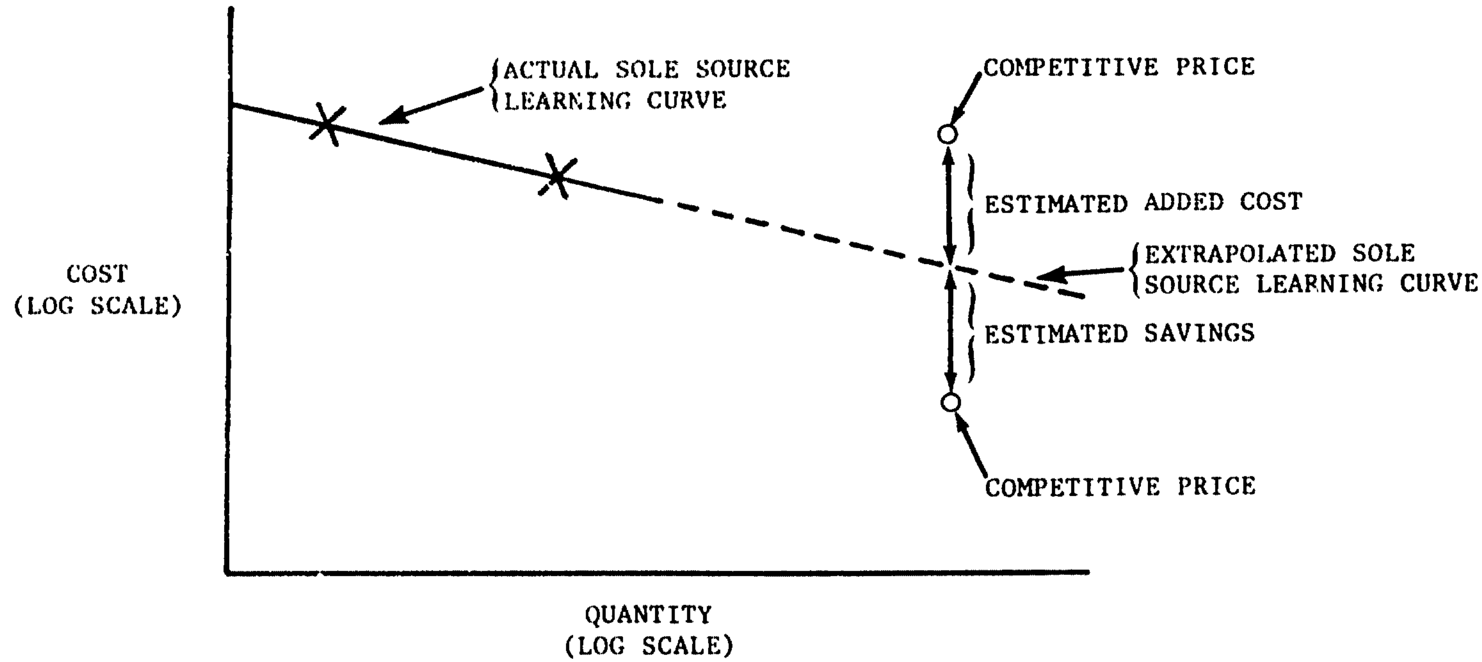


Fig. 3.2--Methodology for estimating effect of competition on price

accurate when applied to a particular industry within that sector. Even within a given industry, experience may vary significantly among the firms which comprise it. Also, some of the costs included in the available data were already converted to constant year dollars and required another adjustment by what could have been a different index. Hence, inflation factors have a large margin of error and adjusted costs should not be interpreted too literally; an apparent added cost or savings of, say, 5 percent could be entirely due to the factors used.

Three sets of "official" inflation factors are shown in Table 3.2. They are used by USAF for the procurement of all types of Air Force items (AFP-173-13, *USAF Cost and Planning Factors Guide*), by the Army Aviation Systems Command (AAVSCOM) for the procurement of avionics equipment, and by the Office of the Secretary of Defense (OSD) for the procurement of all types of military items. Significant discrepancies are observed between pairs of years and, while there is no apparent systematic bias to invalidate an aggregate analysis, caution should be used in drawing specific conclusions for individual cases.

Once constant year dollars were calculated, sole source learning curves were obtained by regressing cost vs. quantity. Like any regression, their explanatory power for the cases included may be measured statistically by the coefficient of determination ($r^2$).

Two types of learning curves are commonly used: unit curves and cumulative average curves. Unit curves are plotted and calculated based upon the midpoint price and quantity for each lot. Cumulative average curves are plotted by lot based upon the cumulative average cost for all units produced (cumulative average cost is the total cost for all units divided by the total number of units). Both types of curves theoretically have identical slopes for the same item. However, several actual cases were observed where different slopes were obtained for the same item depending upon how the data were used. The differences occurred because lot midpoints which were outliers for unit curves were smoothed out by cumulative averaging. This resulted in consistently higher $r^2$s for cumulative curves.[52] All of the studies considered above

[52]When data exhibit significant scatter, several different slopes may yield similar $r^2$ statistics.

Table 3.2

COMPARISON OF SELECTED ECONOMIC ADJUSTMENT INDEXES
(TO BASE YEAR FY72)

| FY | AFP-173-13 | AAVSCOM AVIONICS | OSD* |
|---|---|---|---|
| 55 | 1.420 | - | 1.534 |
| 56 | 1.458 | - | 1.450 |
| 57 | 1.355 | - | 1.349 |
| 58 | 1.342 | - | 1.339 |
| 59 | 1.309 | 1.408 | 1.312 |
| 60 | 1.320 | 1.379 | 1.327 |
| 61 | 1.294 | 1.342 | 1.300 |
| 62 | 1.309 | 1.321 | 1.318 |
| 63 | 1.307 | 1.310 | 1.315 |
| 64 | 1.299 | 1.288 | 1.309 |
| 65 | 1.269 | 1.263 | 1.277 |
| 66 | 1.247 | 1.235 | 1.255 |
| 67 | 1.219 | 1.188 | 1.226 |
| 68 | 1.191 | 1.162 | 1.196 |
| 69 | 1.151 | 1.116 | 1.155 |
| 70 | 1.098 | 1.071 | 1.101 |
| 71 | 1.038 | 1.018 | 1.038 |
| 72 | 1.000 | 1.000 | 1.000 |
| 73 | 0.956 | 0.972 | 0.956 |
| 74 | 0.883 | 0.923 | 0.868 |
| 75 | 0.759 | 0.841 | 0.717 |

*Adjusted from base year FY78.

used unit curves for estimating the effects of competition, a practice which led to different and arguably less reliable findings than would have been obtained using cumulative average curves.

The most important observation made concerning the use of learning curves to estimate the effect of competition was that the final sole source purchase was often above or below the calculated learning curve slope. A final sole source point below the calculated slope could indicate that the firm was improving its efficiency as a reaction to the impending competition. A final sole source point above the calculated slope could mean that it was taking advantage of its sole source position and maximizing profits while still able to do so. Of course, assumptions regarding the reason for the location of the final sole source point would be speculative. Nonetheless, it does not seem reasonable to assume that a sole source buy would be more expensive per unit than the immediately preceding one, yet that assumption is implicit in many of the reported cases.

Specifically, of the 46 cases shown in Table 3.1, 25 were suitable for analysis in that competition was actually implemented following two or more sole source procurements and complete cost/quantity data were available. Of these cases, five had only two sole source procurements so that the final purchase was on the learning curve slope by definition. Thus, out of the cases where more than two sole source procurements had been held, the final sole source lot midpoint was above the learning curve in six cases and below it in twelve cases. When it was above the curve, it was only slightly so. However, when it was below the curve, it was usually significantly so. If it is assumed that the final sole source buy would be more significant than the slope at that point in estimating the next sole source cost, then savings were overestimated on the average, inasmuch as about 50 percent of the final buys were below the slope. Arbitrarily weighting a particular data point is not statistically acceptable and, while a preferred alternative to extrapolating a sole source learning curve in order to estimate its future cost performance has not been identified, the potential pitfalls inherent in this methodology are acknowledged.

Another issue to be considered regarding the analytical methodology is the quantity for which the effect of competition should be measured. The 1974 IDA and the ARINC studies were concerned with identifying savings achieved for the initial competitive buy while the APRO study was concerned with the effect of competition on total program cost. The first approach leads to overly optimistic expectations, since savings for the first competitive buy were generally found to be greater than those resulting from subsequent buys. As noted previously, the APRO approach yields different results depending upon the point in the program at which competition was instituted. A third measure was developed for this study, which is simply the percentage of added cost or savings found for the total recurring production program divided by the portion of the program for which competition was held. This measure may be more policy-relevant since it indicates the percentage of added costs or savings that might have been realized by establishing competition at the outset of production.

While the measures discussed above may be applied to both dual source and winner-take-all competitions, those involving the entire production program may be misleading in cases where one or more split-buys were held as an intermediate step prior to winner-take-all competitions. Therefore, the competitive effect of split-buys is estimated here only for the actual quantity for which dual source competitions were held.

In three of the split-buy cases, one or more educational buys were awarded to qualify the second source. The difference between the average unit cost of these buys and the average unit cost for the sole source during the same time period may be considered as an added nonrecurring cost or savings.

*Data Bias: the Pre-1970 Electronics Industry.* The studies from which the competitive data base used here was compiled were completed in the middle to late 1970s. Therefore, few items included in them were procured during the 1970s. Most of the items were exclusively or primarily electronic in content. Both of these factors are significant because the weapon systems acquisition process has changed in important ways since 1970 and the electronics industry is sufficiently different

from other sectors of the defense market that experience related to it may not be more widely applicable. These issues are discussed below.

Thirty-eight of the 46 items included in Table 3.1 were electronic equipment and a significant portion of the other items (e.g., complete missiles) was comprised largely of electronics. This is significant because the electronics industry's R&D and sales are driven primarily by the commercial market rather than the military market. The electronics industry does not require the high capitalization of the aircraft industry, the turbine engine industry, or a number of other related mechanical industries. Thus, entry into its market by new, smaller firms is more common than in the others.

The norm for the electronics industry appears to be relatively small contracts spread among many manufacturers who may rapidly adapt their facilities to produce a range of products. This makes it possible to have annual winner-take-all competitions based upon data packages without the necessity of utilizing educational contracts, licensing, or leader company procurement (see Chapter II). Also, the existence of interchangeable products produced by several firms often makes competition feasible between alternative items. Therefore, the same level of savings experienced by relatively simple electronic items should not necessarily be anticipated when competition is introduced into the procurement of complex structural or mechanical items (e.g., ships, tanks, airframes, and engines).

Production for 42 of the items shown in Table 3.1 began before 1970 and ended after 1972 for only ten. This is significant because David Packard, former Deputy Secretary of Defense, initiated several policy changes during the 1970s which were aimed at improving cost, schedule, and performance characteristics of the weapon systems acquisition process. These changes included, among others: the establishment of the Defense Systems Acquisition Review Council (DSARC) to provide high level program reviews; the establishment of the Cost Analysis Improvement Group (CAIG) to provide independent cost estimates; the implementation of Design to Cost; and an increase in program managers' authority, responsibility, and support. Together, these policies institutionalized a greater recognition and concern for cost and, thereby, created a systems acquisition environment in the 1970s different from that of the 1960s.

A Rand study provided quantitative comparisons of major defense programs from the 1960s and 1970s.[53] Rand found that the annual rate of cost growth for programs in the 1970s was one to three percentage points less, on the average, than for programs in the 1960s.[54] Although other factors could have contributed to the lower rate of cost growth in the 1970s, the study found it probable that the acquisition policy changes introduced by Packard were the major contribution. Thus, the impact of policy changes made in the 1970s regarding cost control may make it unreasonable to expect the same level of savings from competition in the 1980s as in the 1960s.

*Data Inconsistencies.* In addition to systematic problems with the available data on competition which may limit their broad applicability to future policy decisions, a number of reported cases had apparent inconsistencies which made them unusable for this analysis. Thus, out of the 46 cases reported, only 25 were used in the quantitative analyses presented later in this chapter. The following examples of such inconsistencies illustrate some of the problems.

- The Walleye I Missile Guidance and Control system was produced by Martin under four sole source contracts, after which the data sources indicate that competitions were held, all of them won by Hughes. However, it is unlikely that competition actually existed in this program because the initial Hughes price was 3.6 times the final Martin price. Furthermore, Martin sued the government for $35M because of an allegedly faulty data package. Thus, it appears that Martin dropped out of the program and that Hughes took its place as sole source.
- The AN/ARC-131, a light weight, multi-channel airborne radio set that provides two-way communications for the air crew, was developed by Magnavox as sole source. Magnavox experienced a

[53]Edmund Dews, Giles K. Smith, Allen Barbour, Elwyn Harris, and Michael Hesse, *Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s*, The Rand Corporation, R-2516-DR&E, October 1979.

[54]Ibid., p. 56.

101.8 percent learning curve. A competition held for 614 units was won by Defense Electronics, a Division of DEI Industries, with a bid about 70 percent of the previous Magnavox cost. However, Defense Electronics experienced financial problems and the contract was terminated for default. No deliveries were made. Another sole source contract was awarded to Magnavox and its learning curve for the final buy was calculated at 137.9 percent.

ARINC reported that this case represented savings of 28.3 percent (based on the Defense Electronics bid price only and ignoring the default). APRO showed a loss of 2.1 percent. Neither commented on the possible implications of the negative learning curve experienced by Magnavox. Since the product was developed at Magnavox's own expense, was it already on the flat part of its learning curve? Did the increase after Defense Electronics' default represent recognition of the elimination of any reliable competitive threat, or was it simply due to the start-up costs caused by a cold assembly line?

- The AN/PRC-77 is a short-range, manpack, transistorized, frequency-modulated portable radio set in a water-tight case. It provides field communication between company- and battalion-sized Army units. It was developed by RCA, which produced the first four lots (19,635 units) while maintaining a learning curve slope of 89.8 percent. Sixteen subsequent lots were competed for and produced by several other companies. Savings of about 32 and 25 percent were estimated for the first lot and total program, respectively. These estimates, however, ignore several important qualitative facts: Delays were experienced under contracts to E Systems, Cincinnati and Bristol; Sentinel Electronics defaulted; the Hamilton Watch contract was novated; and claims and/or awards totaling $20.5M were made. When these points are considered, a case could be made that competition was not successful since it is likely that a multi-year contract with the initial source could have achieved the same costs without the claims, defaults, and delays.

This case was well documented by APRO and reported by IDA

and ARINC as well. The much more highly detailed data provided by APRO indicate that the IDA and ARINC data were both incomplete and incorrect.

- The PP-4763/GRC is a solid state power supply developed by Christie Electronics, which also produced the first lot of 1,818 units. Two subsequent competitions were won by other companies but the resultant contracts terminated for default. Christie was given another sole source award for 198 units. Christie experienced a positive (110.9 percent) learning curve--possibly the result of a five year hiatus, although realization of its monopolist position could also have been a factor. Two competitions were subsequently held and lower costs resulted. ARINC indicated savings of 62 percent based on the bid prices for the defaulted contracts. APRO calculated slight savings (0.3 percent) for the total program but failed to address the reason for Christie's positive learning curve, which in fact formed the basis for indicating that savings resulted from the competition.

Special circumstances similar to those identified above existed in other cases as well. Savings identified as the result of competition in each case may have been more apparent than real. Even if such discrepancies have not systematically biased the entire sample, they do indicate that costs or savings following a competition may result from factors other than the competition itself.

*Summary* Systematic biases and specific problems related to the cost/quantity data available for competition combined with limitations inherent in the analytical methodology reduce the confidence which may be placed in quantitative findings. Nevertheless, it is important to examine the data to determine whether trends are apparent regarding the effect of split-buy and winner-take-all competitions, considered both separately and comparatively. These analyses are presented in the following sections.

## Analysis of Competitive Split-Buys

Ten items were identified in Table 3.1 as having been subjected to one or more split-buy competitions during the course of their procurement. They included: one bomb, one torpedo, three complete missiles, and five missile guidance and control systems. Although competitive split-buys are generally quite similar to the dual source competitions covered in this study, a significant difference may exist for some of those discussed below. Specifically, in half of these cases, competitive split-buys were used as an intermediate step between sole source procurement and winner-take-all competition. Therefore, there may have been a greater incentive for both sources to reduce their costs in anticipation of forthcoming winner-take-all competitions than for them to employ a strategy which would seek to maximize profits by maintaining a higher price.

Each case[55] is described briefly below to indicate any interesting or unusual circumstances which might aid in interpreting the quantitative information which is subsequently provided.

*Bullpup AGM-12 Guidance and Control.* The Bullpup is an air launched missile for attacking surface targets on land or sea. Guidance is by radio command link from the launching aircraft. The Martin Co. was the sole source producer for the first four lots (10,895 units), after which the Maxson Co. was introduced as a second source. Several competitive split-buys followed with Martin producing 26,137 units and Maxson 4438 units. A final buy-out competition for 3500 units was won by Maxson with a bid less than half its lowest previous price.

Martin experienced an 82 percent learning curve slope[56] as a sole

[55]The Dragon missile case is not described because no cost data were available for it

[56]Since learning curve slope plays an important role in the analysis of the effect of competition on price, the following information is provided as a frame of reference. A positive slope (over 100 percent) indicates that a firm is becoming less efficient as quantity increases. Slopes between 90 and 100 percent indicate relatively little learning is taking place, slopes from 80 to 90 percent are fairly normal, and slopes below 80 percent indicate a very efficient producer. These comments are general; they vary by industry and may not be appropriate for any particular case.

source. During the split-buy competitions, its price dropped significantly, although its learning curve slope during those lots became more shallow (96.4 percent). Its overall learning curve slope was 79 percent.

*TOW.* TOW is a heavy assault weapon designed primarily to destroy enemy tanks, pill boxes, and armored vehicles. The missile is tube launched, optically tracked, and wire guided. The system is composed of the missile, launcher, and ancillary equipment. Hughes developed the missile; Chrysler was chosen over Philco Ford and Varo as the second source.

Hughes produced 18,250 units and Chrysler produced 2885 units before competition was held. Hughes won 62 percent of the initial split-buy quantity with a bid 12 percent below Chrysler's and then won four subsequent winner-take-all competitions.

Significant savings are indicated as a result of Hughes' shallow sole source learning curve slope (93.9 percent). Although the reasons for Hughes' shallow slope are unknown, a sole source could take advantage of its monopolist position to maximize profits in anticipation of a forthcoming competition.

*Rockeye Bomb.* The Rockeye Bomb was produced by Honeywell as sole source from 1967 until 1972, when Marquardt Corp. was introduced as the second source. According to IDA, competition took place.[57] This conclusion is, however, unsupported by the data: The higher cost producer received the larger share in all cases said to have been competitive.[58] For example, in FY72, Honeywell sold 44,518 bombs at an average unit cost of $1970, compared to Marquardt's sale of 12,000 bombs for $1770, or ten percent less. Furthermore, Honeywell's learning curve slope remained relatively constant throughout the program (83.8 percent before introduction of the second source compared to 81.2 percent afterwards).

[57] 1974 IDA Report, pp. 14-28.

[58] A fundamental ground rule for dual source competition is that the low bidder will produce the greater quantity.

A review of the data indicates that it is possible that Marquardt was introduced because Honeywell had insufficient capacity to produce the entire required quantity. (Honeywell produced no more than 24,000 bombs a year as sole source, compared to a total quantity of about 57,000 produced during FY72 when a second source was introduced.)

*Shillelagh Missile*. Shillelagh is a direct fire, boost glide, line of sight missile. Philco Ford Aeronautics was the sole source producer for the first two lots (about 18,000 units) before Martin Marietta was introduced as a second source and apparently given an educational contract. Although IDA indicated that a competitive split-buy was subsequently held, the data contradict this assertion as the higher cost producer received the larger share of the buy.[59]

Philco Ford maintained a constant learning curve slope throughout the program (76.0 percent as sole source, 76.3 percent including split-buys, and 76.1 percent overall, including the buy-out competition which it won). However, it could be argued that its steep learning curve slope resulted from the competitive threat posed when Martin was introduced during the second production year (it is unclear whether Martin was introduced before or after Philco Ford was awarded that buy).

*Sparrow AIM-7F Guidance and Controls*. The Sparrow AIM-7F is one of several versions of the Sparrow air-to-air missiles designed by Raytheon and produced over the past 20 years. The operational requirement for the Sparrow AIM-7F was identified in 1965. Its guidance and control (G&C) system utilized a solid state design which proved more difficult to develop than anticipated and therefore stretched the development effort over eight years. Near the end of the development effort, the Navy decided to introduce dual source production. Raytheon began sole source production in 1972; General Dynamics Pomona (GD) was selected as the second source in 1973. However, the initial dual source competition was not held until 1977 because of the long time required to qualify GD as a second source and to provide it with sufficient tooling to enable it to compete for a major share of the required annual quantity.

[59] 1974 IDA Report, pp. 14-26; APRO Report, pp. 31-36.

Four split-buy competitions were held, the third won by GD. Discussions with NAVAIR personnel indicate that, because GD lost money on the competition it won, it increased its price by about 30 percent for the final competition.

Data indicate that dual source competition significantly increased the cost of the Sparrow AIM-7F procurement, primarily because Raytheon maintained a very steep learning curve slope throughout the program (75.3 percent for its sole source awards and 76.5 percent for its entire production). Of course, it could be argued that the competitive threat posed by GD provided the incentive for such a steep slope.

*Sidewinder Missiles Guidance and Control*. Sidewinder is a short range, infrared, air-to-air missile used on Navy and Air Force fighter aircraft. Cost and quantity data were reported for two versions of the guidance and control system: AIM-9B and AIM-9D/G.

For the Sidewinder AIM-9B, Philco Ford produced the first lot (272 units) as sole source, after which General Electric was introduced as the second source. The next three lots were competitive split-buys. They were followed by nine winner-take-all competitions. Only one sole source buy was made. Therefore, a sole source learning curve cannot be calculated to estimate the effects of competition. An analysis of learning curves did not allow inferences to be made concerning any possible effects of competition. For example, Philco Ford had a learning curve slope of 82.3 percent for the entire program. If Philco Ford produced all units as sole source and maintained that slope, the total program cost would have been less. It is also interesting to note that the learning curve slopes for both Philco Ford and General Electric were about three percent greater during the split-buy phase.

Philco Ford produced the first six lots (425 units) of the Sidewinder AIM-9D/G as sole source. Raytheon was selected as a second source and two split-buy competitions were held during which Philco Ford increased its price to about three times its final sole source price. Six winner-take-all competitions followed and all were won by Raytheon, which experienced a learning curve slope of 117.7 percent (in apparent reaction to the absence of a true competitive threat). Thus, it is estimated that competition significantly increased the cost of this program.

*Mark 46 Torpedo.* The Mark 46 Torpedo was the first U.S. torpedo powered by a solid fuel motor. It was developed by the Naval Undersea Center. Aerojet was established as the sole source for the Mod 0 version. However, a Mod 1 version was soon developed and Aerojet and Honeywell were both established as producers with small buys (100 units). Aerojet established a learning curve slope of 81.9 percent throughout the production of Mod 0 and the educational buy of Mod 1. On the first competitive split-buy, its price was 13.9 percent below the estimate based on its learning curve. However, when the Aerojet and Honeywell prices were combined, an additional cost of 7.8 percent was indicated for the first competitive split-buy. Aerojet's cost for the next competitive split-buy increased substantially (58 percent) and Honeywell won the larger share of that buy as well as both of the following two winner-take-all buys. It is difficult to determine what happened from the available data, although estimates indicate that the cost of this program increased significantly as a result of dual source competition.

*Shrike Missile.* The Shrike is a Navy developed air-to-surface missile. Its procurement history indicates that competition was held for its guidance and controls and its wings and fins. Texas Instruments was the sole source for the initial lot on a directed buy basis. Thereafter, competitive buys were held with Texas Instruments and Sperry Rand participating. It is impossible to estimate the effect competition may have had on cost because there was only one precompetitive sole source buy and, therefore, a sole source learning curve could not be calculated.

The quality of the available cost/quantity data for Shrike is questionable because of significant differences found in comparing the two sources for it.[60] Also, in some cases, the larger quantity apparently went to the higher bidder. There is no evidence to suggest that the effect of competition was significant one way or another. For example, the Mod 3 guidance subsystem, which accounts for 84 percent of the total quantity of Shrike guidance subsystems procured, was examined independently and the following was determined:

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[60] 1974 IDA Report, pp. 14-40; Kluge and Liebermann, *Analysis of Competitive Procurements*, pp. 98-112.

| | *Texas Instruments* | *Sperry Rand* |
|---|---|---|
| Quantity | 9250 | 5967 |
| Cumulative Average Cost | \$3634 | \$4166 |
| Learning Curve Slope | 85.5 | 93.5 |

Thus, the initial source (Texas Instruments) maintained a moderate slope and sold a larger quantity for a lower price than the second source.

*Summary of Competitive Split-Buy Cost/Quantity Data*. The effect of competitive split buys on price was estimated in accordance with the analytical methodology described above. As shown in Table 3.3, recurring production cost savings were estimated for three items and added costs for four. No estimates could be made for three items because Sidewinder AIM-9B G&C and Shrike had only one sole source buy and no cost data were available for Dragon.

The theoretical discussion provided above led to the a priori expectation that the greatest cost savings would result from competing a simple item (as indicated by a relatively low cost) procured in large quantities when the sole source experienced a relatively shallow learning curve slope. While it could be argued that such trends generally are supported by the data shown in Table 3.3, significant exceptions are noted. The descriptions provided for the Rockeye Bomb and Shillelagh programs indicate, however, that competition may have been absent in the split-buys held for them. In addition, competition did not exist in the Sidewinder AIM-9D/G G&C case in the sense that both firms involved did not seek the larger quantity by bidding down the price. When the remaining four items in Table 3.3 (Bullpup, TOW, Sparrow, and Mk46 Torpedo) are considered alone, the a priori expectations are generally fulfilled, since the two cases where savings are estimated (Bullpup and TOW) had higher sole source learning curve slopes and quantities and lower unit costs than the two cases (Sparrow and Mk46) where added costs are estimated.

Another a priori expectation was that savings would be greater when split-buy competitions were followed by winner-take-all competitions, as both producers would try to improve their efficiency rather than employ other strategies to maximize profits. Three of the four cases shown in

Table 3.3

SELECTED COST/QUANTITY DATA FOR COMPETITIVE SPLIT-BUYS

| Item | Competitive Split-Buy % Savings or (Cost)* | $CAC_{10,000}$ \$FY72 (000)† | Initial Sole Source Learning Curve Slope % | Quantities: Initial Source Pre-Competition | Quantities: Second Source Education | Quantities: Competitive Split-Buy | Quantities: Winner-Take-All | Quantities: Total |
|---|---|---|---|---|---|---|---|---|
| Bullpup Missile G&C | 25.8 | 7.6 | 82.0 | 10,895 | 0 | 30,575 | 3,580 | 45,050 |
| TOW | 22.6 | 5.6 | 97.7 | 18,250 | 2,885 | 10,500 | 46,837 | 78,472 |
| Rockeye Bomb | 3.7 | 4.3 | 83.9 | 53,913 | 0 | 72,558 | 0 | 126,471 |
| Shillelagh Missil | ( 6.3) | 7.1 | 76.3 | 17,945 | 4,960 | 29,386 | 35,903 | 88,194 |
| Sparrow AIM-7F G&C | (20.5) | 46.7 | 75.6 | 1,805 | 295 | 7,124 | 0 | 9,224 |
| Sidewinder AIM-9D/G G&C | (22.0) | 3.8 | 86.4 | 425 | 0 | 2,770 | 6,760 | 9,995 |
| Mk46 Torpedo airframe & G&C | (36.4) | 28.9 | 81.8 | 1,650 | 0 | 7,298 | 3,198 | 12,146 |

*Actual competitive split-buy costs divided by extrapolation of initial sole source learning curve for competitive split-buy quantity.

†Estimated based on initial source cumulative average cost (CAC) equation for comparability.

Table 3.3 for which added costs were estimated had significant winner-take-all competitions. Even though the applicability of two of these contrary cases was questioned, this expectation is not supported.

At a minimum, the data in Table 3.3 indicate that split-buy competitions sometimes significantly increase recurring production costs. Although the reasons for this are arguable, the Sidewinder AIM-9D/G G&C case demonstrates that, even when contractors are able to compete, they may not be willing to do so. It may be inferred from these facts that dual source competition should not be established to effect cost savings unless the decision can be supported by a well defined rationale as to why it is appropriate for the particular case under consideration.

Cost/quantity data for which only winner-take-all competitions were held following two or more sole source buys are analyzed in the following section to determine whether they differed significantly from the split-buy competitions considered above.

### Analysis of Winner-Take-All Competitions

Table 3.1 indicated that only winner-take-all competitions were held for 28 items following sole source production. Eighteen of these cases provided adequate data to calculate the effect of competition on the first competitive lot, the total program, and the total program divided by the percentage off the program for which competition was held. The analytical methodology used to estimate these effects is discussed above.

It was anticipated that greater and more consistent savings would result from winner-take-all competitions than from competitive split-buys for several reasons. The fact that a product could be produced by a second source without assistance from or overlap with the initial source is evidence of relatively simple technology. Similarly, the fact that a product could be produced by a different manufacturer every year also evidences a relatively simple technology by indicating minimal start-up requirements (such as training and tooling). Also, a single producer (whether a sole source or winner of a competition) is generally more efficient because of economies of scale, less excess capacity,

amortization of fixed expenses, and greater learning, as discussed above.

Analytical results for winner-take-all competitions are presented in Table 3.4. Savings were indicated for 17 of these 18 items. Average estimated savings were on the order of 40 percent both for the first lot and for the percent of savings for the total program divided by the percent of the program for which competition was held. Thus, as anticipated, greater savings were observed for programs where only winner-take-all competitions were held, compared to those where split-buy competitions were held. It is cautioned, however, that the magnitude of the estimated savings is probably overstated to some extent because of a problem with the analytical methodology, as discussed above. Specifically, in nine cases, the final sole source buy was significantly below the learning curve.[61] Since it could be reasonably argued that the final sole source buy would have a greater influence on the next sole source buy than those which preceded it, estimated savings could diminish by as much as about 15 percent. Still, a 25 percent savings would be most significant.

It was noted that competitive savings might not be expected for split-buy cases if their unit costs were relatively high. The Standard Missile, which had a cumulative average cost significantly greater than that of the other items in Table 3.4, was the only case where a loss was estimated. Thus, this expectation might be applicable to winner-take-all competitions as well as to competitive split-buys.

It is reasonable to conclude that split-buys should not be used in lieu of winner-take-all competitions when the latter are feasible and the exclusive objective is to reduce cost. Whereas added recurring production costs were estimated for only one of 18 exclusively winner-take-all cases, added costs were estimated for over half of the split-buy competitions. Therefore, it may be concluded that it is inappropriate to expect the same level of savings from all types of competition.

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[61]It was significantly above in only one instance.

Table 3.4

SELECTED COST/QUANTITY DATA FOR WINNER-TAKE-ALL COMPETITIONS

| System | Total Quantity | CAC* ($FY72) | Percent Savings or (Added Cost): First Lot Competed | Total Program | % Savings/† % Competed |
|---|---|---|---|---|---|
| Mk48 Torpedo (warhead)‡ | 1,032 | 9,717 | 54.3 | 23.7 | 50.9 |
| Mk48 Torpedo (elec. assy.) | 1,034 | 12,603 | 37.5 | 11.6 | 24.9 |
| Standard Missile | 5,927 | 51,999 | (13.6) | ( 2.4) | ( 2.9) |
| Hawk Missile (motor parts)‡ | 14,498 | 1,534 | 33.4 | 19.9 | 46.7 |
| TD-660 Multiplexer‡ | 3,593 | 9,141 | 35.4 | 14.2 | 35.9 |
| AN/GRC-103 Radio Relay | 963 | 28,863 | 59.1 | 11.9 | 53.8 |
| APX-72 Airborne Transponder** | 27,529 | 3,014 | 32.5 | 9.4 or (1.6) | 28.4 or (3.1) |
| SPA-25 Radar Indicator‡ | 2,011 | 8,919 | 25.3 | 14.2 | 75.1 |
| TD-352 Multiplexer | 3,741 | 7,399 | 58.1 | 36.0 | 58.0 |
| TD-204 Cable Combiner‡ | 8,733 | 3,430 | 56.2 | 35.5 | 51.2 |
| CV-1548 Converter | 11,583 | 3,088 | 63.9 | 40.2 | 61.0 |
| TD-202 Radio Combiner‡ | 3,692 | 3,258 | 58.1 | 36.5 | 51.1 |
| Aerno 60-6042 Elec. Cont. Amp. | 666 | 7,326 | 53.2 | 8.5 | 43.1 |
| MD-522 Modulator-Demod. | 4,805 | 3,112 | 61.4 | 25.9 | 55.0 |
| AN/PRC-77 Manpack Radio | 143,347 | 708 | 32.2 | 25.2 | 29.2 |
| FGC-20 Teletype Set†† | 1,980 | 2,091 | 32.6 | 4.0 | 28.8 |
| Aerno 42-2028 Generator | 1,679 | 645 | 10.7 | 7.3 | 19.0 |
| Aerno 42-0750 Voltage Reg. | 2,175 | 110 | 48.6 | 29.9 | 58.1 |
| Average | | | 41.1 | 19.5 | 42.6 |

*Cumulative average cost (CAC) paid for the entire production quantity.

†Total program savings percentage from prior column divided by the percentage of the total quantity for which competition was held.

‡Last sole source buy significantly below learning curve slope.

**Commonality between the RT859 and RT859A models of the APX-72 is at issue: if common, total savings; if not, total loss.

††Last sole source buy significantly above learning curve slope.

## THE EFFECTS OF SECOND SOURCES ON OTHER LIFE CYCLE COST CATEGORIES

### Nonrecurring Costs

It is anticipated that nonrecurring costs will usually be incurred in establishing a second source. They might include expenses for: selection of the second source; advanced and/or full scale development (if an alternative design is used), or government purchase of data rights with or without technological assistance from the developer (if the same design is produced by another firm); tooling and test equipment; qualification testing; and second source educational contracts. Another unanticipated but not uncommon nonrecurring cost associated with competition is that of claims filed against the government by winners who suffered a loss as a result of bidding too low a price. The usual basis for claims was technical data packages which were allegedly incomplete or incorrect.

Nonrecurring cost data were infrequently reported in the studies on competition and, even when they were, they were not well documented. Estimates of nonrecurring costs related to educational buys for the second source were calculated using the methodology described above. The APRO and TRI reports estimated second source nonrecurring costs by subtracting the total hardware recurring price from the total contract price. They also included contractual support prices paid to the sole source contractor for support of the second source contractor and any additional costs due to program stretchout required to develop a second source.[62] Rucker documented claims resulting from the establishment of competition.[63] This information is summarized in Table 3.5 for items for which split-buy competitions were held.[64] This is not a

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[62]Kluge and Liebermann, *Analysis of Competitive Procurements*, p. A-7.

[63]Untitled notes on competition.

[64]Very few nonrecurring cost data were available for items for which only winner-take-all competitions were held. Nonetheless, the following claims ($FY72) were reported by Rucker: AN/PRC-77--$12.0M, Walleye Missile--$35.0M, Standard Missile--$9.0M. In addition, nonrecurring costs in the amount of $4.8M and $11.4M ($FY72) were incurred to establish competition for the Walleye and Standard Missiles, respectively.

Table 3.5

SUMMARY OF SOME NONRECURRING COSTS RELATED TO COMPETITIVE SPLIT-BUYS

(Millions of $ FY72)

| Item | Educational Buys | Other Reported Non-recurring | Claims |
|---|---|---|---|
| Bullpup Missile G&C | 0 | 1.1 | 16.0* |
| TOW | 6.8† | NA | NA |
| Rockeye Bomb | 0 | NA | NA |
| Shillelagh Missile | ( 8.0)† | 0.7 | NA |
| Sparrow AIM-7F G&C | 18.6† | 43.5 | NA |
| Sidewinder AIM-9B | 0 | 1.2 | NA |
| Sidewinder AIM-9D/G | 0 | 2.3 | 7.0 |
| Mk46 Torpedo | 0 | 18.0 | NA |
| Shrike | 0 | 4.1 | NA |

*Amount shown was contractor overrun. A claim was not filed to recover it.

†By incorporating the educational quantity produced by the second source into the sole source learning curve, estimates of added cost or savings shown in Table 3.3 for these three items would change as follows:

| | From % | To % |
|---|---|---|
| TOW | 12.0 | 11.0 |
| Shillelagh Missile | ( 6.3) | (10.4) |
| Sparrow AIM-7F G&C | (20.5) | (31.4) |

comprehensive listing of nonrecurring costs associated with split-buy competitions; it is only a summarization of limited, available data.

Of course, estimated savings are reduced or added costs are increased by including nonrecurring costs in evaluating the effects of competition. Since these costs are incurred at the beginning of a program, a discounted present value analysis would weight them more heavily than subsequent added costs or savings.

### Operation and Support Costs

The operation and support cost implications of establishing a second source should be considered to provide a comprehensive life cycle cost evaluation of the effects of competition. None of the studies on competition included any cost data for this category. However, it should be noted that all costs reported were for competition between identical items. There is no reason to assume that they would affect O&S costs.

Some who favor increased competition during procurement have stated that it improves system reliability and, therefore, would reduce O&S costs. However, data have not been provided to support this assertion. If such an effect existed, it would probably be a spinoff from attempting to simplify the product so that it could be produced at a lower cost (i.e., it could be argued that simple products are inherently more reliable--all else being equal), or to reduce the number of items failing quality assurance inspections and associated rework costs. In any event, it is unlikely that manufacturers would invest to improve reliability per se if it were not a criterion for the award.

## CRUISE MISSILE CASE STUDIES: LIFE CYCLE COST ANALYSIS

The necessity for considering all costs relevant to a decision to establish dual source competition was stressed above. It is anticipated that a substantial investment will often be required to select and qualify a second source in order to establish dual source competition. The amount of this investment must be estimated together with any additional support costs which might be incurred. Then, the resultant competition should be evaluated to determine the expected level of

savings required to break even after recouping any added costs for establishing a second source and maintaining two alternative items in the stockpile.

Since no effective methodology has been developed to estimate the effect of dual source competition on recurring production costs, theory regarding factors which might affect the competition was reviewed. Available data on split-buy competitions were analyzed as a proxy for dual source competition and data on winner-take-all competitions were analyzed as a best case for competition. Neither economic theory nor data on split-buy competitions offer reason to expect savings from dual source competition. Nevertheless, specific cases could exist where it would be appropriate to establish a second source in anticipation of savings from dual source competition. The selection of second sources for the cruise missile engine and guidance system provides instructive examples of the role of life cycle cost analysis in a decision to establish dual source competition because they pose very different problems and together illustrate a wide range of issues that must be addressed.

Second source alternatives considered for the cruise missile engine and guidance system were discussed in the second section. In each case a choice was made between selecting a second producer for the existing design or for a different design with the same form, fit, and function. The life cycle cost estimates (exclusive of recurring production costs) made for each case are presented in Table 3.6. The estimates represent the additional costs that would be incurred to establish second sources. The bases for many of the estimates are not discussed because they derive from proprietary data provided by manufacturers with an interest in the anticipated dual source competition. However, key assumptions are discussed and the sensitivity of the estimates to them is explored. Estimates for the alternative designs are shown as ranges to represent optimistic and pessimistic assumptions.

Table 3.6 indicates that RDT&E costs account for the most significant cost difference between an alternative development and the production of the same design by a second source. Developing and testing a new design to the point where it is fully qualified and ready for production is usually a significant task. Even though the key

Table 3.6

SUMMARY OF COST ESTIMATES OF SECOND SOURCE ALTERNATIVES
FOR CRUISE MISSILE SUBSYSTEMS

(Millions of $ FY78)

| | Engine | | Guidance | |
|---|---|---|---|---|
| | Same Design | Alternative Design | Same Design | Alternative Design |
| RDT&E | ( 0 ) | (66.9-109.7) | (0) | (19.2-28.2) |
| Advanced development | 0 | 26.9- 46.0 | 0 | 0 |
| Full scale development | 0 | 32.2- 48.1 | 0 | 16.8-21.2 |
| Qualification test | 0 | 7.8- 15.6 | 0 | 2.4- 7.0 |
| NONRECURRING INVESTMENT | (19.5) | ( 2.0- 5.5) | (0) | (21.4-22.9) |
| Technology transfer | 15.0 | 0 | 0 | 0 |
| Tooling and test equipment | 4.5 | 2.0- 5.5 | 0 | 21.4-22.9 |
| SUPPORT* | ( 0 ) | ( 3.3- 32.6) | (0) | ( 3.2-32.3) |
| Integrated Logistics Support | ( 0 ) | ( 3.3- 11.6) | (0) | ( 3.2-19.7) |
| Spares | ( 0 ) | ( 0 - 8.3) | (0) | ( 0 - 1.7) |
| Engines | 0 | 0 2.6 | NA | NA |
| Components | 0 | 0 - 5.7 | NA | NA |
| Maintenance | 0 | 0 | 0 | 0 |
| Maintenance Data | 0 | 0.7 | 0 | 0.1 |
| Technical Publications | 0 | 0.5 | 0 | 0.5- 1.2 |
| Support Equipment | ( 0 ) | ( 1.3 ) | (0) | ( 1.2-15.0) |
| Test | - | - | 0 | 0.5-14.3 |
| Training | - | - | 0 | 0.7 |
| Training | 0 | 0.3 | 0 | 1.2 |
| Inventory Management | 0 | 0.5 | 0 | 0.2 |
| Operational Test | 0 | 0 - 21.0 | 0 | 0 -12.6 |
| TOTAL | (19.5) | (72.2-147.8) | (0) | (43.8-83.4) |

*Includes initial provisions and ten years at steady state.

components of an alternative guidance system were essentially available off-the-shelf, it was estimated that full scale development of that system still would cost from $19M to $28M.

The estimated development costs for an alternative engine are even greater ($59M to $94M) inasmuch as no alternative existed previously which could enter full scale development. Teledyne CAE had developed engines for the SCAD and SLCM program design competitions. However, it was perceived that significant additional design effort was required to meet specifications for an alternative cruise engine design. Further, it was not certain that Teledyne had an insurmountable advantage over other interested manufacturers and, if their technical proposals were stronger than Teledyne's, an even higher cost might have been required.

Bench and flight tests are conducted for a complete missile and its components during development (qualification tests) and after it is in the inventory (operational tests). Flight tests are expensive (from about $300K to $500K each) because of the large amount of manpower and equipment required to conduct them. There is great uncertainty associated with the estimates shown for these cost elements because the quantity of additional flight tests which would be required for a component of a different design is a function of policy and it was impossible to find a policy statement (or policymaker) to indicate how an alternative design would be treated in the test process.

While it was generally agreed that a component of the same design would not affect test costs because sufficient tests are scheduled to represent both manufacturers adequately, significant differences of opinion existed among personnel from the government and competing firms regarding the required number of additional qualification tests for an alternative design. The assumption that tests would increase by about ten percent for a form, fit, and function component utilizing standard technology and by over 40 percent for one utilizing new technology was used as a reasonable figure which was accepted by the interested parties.

Periodic operational tests are required after a missile is placed into service. At most, the number of such tests would increase by 10 percent, although any increase might be avoided by a stratified sampling process to assure that each design received sufficient testing.

Nonrecurring investment costs are incurred for technology transfer to prepare another manufacturer to produce an existing design. Nonrecurring investment costs are generally incurred for tooling and test equipment regardless of whether the second source produces an identical or an alternative design. The fact that no cost was estimated for technology transfer or tooling and test equipment for the guidance system is an example of applied marketing/competitive strategy: Litton's proposal to establish Litton Systems Ltd. of Canada as the second source offered to transfer the required technology from Litton Guidance and Control Systems without charge and to capitalize all of the required equipment. The estimate shown for tooling and test equipment for the alternative guidance system is based on an initial bid; it might have been reduced significantly if it had been made part of a competition. The engine case is different because licensing of the WRC design was clearly the best alternative for the government and there was no incentive for WRC to absorb a loss from the transfer of its technology.

The analysis of support costs involved reconciling the opinions of government and contractor personnel regarding which sets of reasonable assumptions and cost estimating models should be used in comparing the alternatives. The a priori assumption was made that an alternative design would significantly increase support costs. However, as shown in Table 3.6, even the worst case indicates a difference of only a few million dollars a year during the operational life of an item.

In both the engine and guidance system cases the estimated life cycle costs (exclusive of recurring production) for the alternative design were substantially greater than the estimated costs for having another firm produce the same design. Thus, production competition involving an alternative design would have to result in greater savings in order to break even, as shown below.

Sole source recurring production cost estimates for the cruise missile engine and guidance system are made using cost estimating relationships of the following form:

$$C = aQ^{b}$$

Where: $C$ = cumulative average cost for $Q$ units

$Q$ = quantity

$a$ = first unit cost

$b$ = learning curve slope.

Or,

$$\text{Engine:} \quad C = 190\ Q^{-.1047}$$

$$\text{Guidance System:} \quad C = 180\ Q^{-.0740}$$

If it is assumed that a total of 5400 units of each item would be produced and that competition would begin after the initial source produced 610 units on a sole source basis, then cumulative average costs for the final 4790 units[65] of \$72.6K and \$92.9K are calculated for the engine and guidance system, respectively, based upon sole source production. Total sole source costs for the 4790 units which would be competed are estimated at \$356.6M for the engine and \$445.1M for the guidance system. Thus, based on the totals shown in Table 3.6, competition involving an alternative engine design would have to produce savings of between 20 percent and 40 percent and competition involving an alternative guidance system would have to produce savings of between 10 percent and 19 percent in order to break even with the sole source case.[66] A much lower level of savings (5 percent) would be required for an identical engine to break even and no savings are required for an identical guidance system because all the added nonrecurring costs for the second source were to be paid by Litton as part of its competitive strategy.

The savings required to break even are averages for the initial source and the second source. If it is assumed that the initial source would maintain the same learning curve slope even if it was not involved

[65] Estimated based upon $CAC_{5400}$ less $CAC_{610}$.

[66] $\dfrac{\$72.2 \text{ or } 147.8M}{\$356.6M}$ for the engine and $\dfrac{\$43.8 \text{ or } 83.4M}{\$445.1M}$ for the guidance system.

in a competition, the entire deficit would have to be made up by the second source over its share of the buy alone.

The time required for the second source to reach the production phase is related to the break even calculations shown above because the smaller the quantity competed, the larger the percentage savings required to offset additional costs. In cases where an alternative design is not fully developed, the risk of delay in reaching the production phase is usually greater than that for transferring technology from the developer of an existing system to another qualified source. Therefore, it is probable that the number of competitive units produced by two sources for the same design would exceed those for alternative designs. Thus, competition between two sources producing alternative engines or guidance systems would have to result in greater savings than would competition between two sources producing identical engines or guidance systems in order to match estimated sole source costs.

Theory provides no reason to assume that dual source competition during production would result in lower costs than would sole source procurement. The limited available data indicate that split-buy competitions have resulted in higher estimated costs slightly more often than savings. Since the cases examined included only identical items, cost savings for alternative items may be even more improbable since they have higher initial costs. Ultimately, any added costs or savings during production would depend upon the willingness and ability of the two sources to compete.

## SUMMARY AND CONCLUSIONS

The data indicated that relatively simple items which were procured in large quantities on an annual winner-take-all basis almost always resulted in savings when compared with estimated sole source costs. In contrast, more complex items for which split-buy competitions were held often resulted in higher costs. Two reasons may be cited as probable causes for these findings:

- The division of a fixed quantity between two producers is generally less efficient than production of the entire quantity by a single source;
- The only effective strategy for a winner-take-all competition is to be the low bidder--there is no prize for second place. This contrasts with split-buy competition where there are alternative means for maximizing profits (or, for avoiding losses).

Data rights and a complete and accurate data package possibly accompanied by technical assistance may often play an important role in dual source competitions because the items involved would be of relatively high technical complexity. This may enable the developer to play a role in determining what kind of competition would be held and who its competitor would be. High technical complexity may also imply a long lead time to qualify a second source, during which the initial source may acquire an insurmountable experience advantage. Furthermore, high technical complexity and long lead time often require high nonrecurring costs for the second source, costs which must be offset by savings during production just to match the performance of a sole source.

Thus, dual source competition should not be implemented as a general policy in order to achieve cost savings during production. However, certain cases may exist where the establishment of dual source competition would be an appropriate means of seeking lower costs. For example, a case where one or more of the following conditions existed might be a good candidate for dual source competition: an inefficient sole source producer, the existence of two traditionally competitive firms, annual production requirements in excess of the capacity of a single source, low nonrecurring costs to establish a second source, and a short time for a second source to become competitive.

In contrast, data suggest that winner-take-all competitions should be established whenever possible in the acquisition of weapon systems, assuming that nonrecurring cost requirements are minimal. Also, it was observed that the threat of establishing competition was an effective

means of obtaining concessions from the sole source or in keeping it on a relatively steep learning curve slope. However, it is cautioned that, while the threat of competition may provide the government with a useful ploy, it may be counterproductive if actually implemented without a willing and able second source.

The information presented in this chapter dealt with the cost effects of competition. Other reasons might exist for establishing dual source competition. They are covered in the next chapter.

# IV. THE EFFECTS OF SECOND SOURCES ON RISKS AND OTHER ISSUES

## RISKS AND EXPECTED OUTCOMES

Every weapon system acquisition program strives to assure the timely delivery of the required quantity of a product meeting performance specifications within the budgeted cost. Advocates of dual source competition have suggested that the existence of two sources will reduce or eliminate risks[1] which prevent achievement of these objectives. However, they have not explicitly identified the types of risk which the establishment of a second source would affect.

Risks associated with a sole source vary markedly from case to case depending upon the item considered and the firm involved. This chapter identifies, defines, and analyzes the types of risk associated with a sole source which might be affected by the establishment of a second source. After a brief, general discussion of risk, it considers the types of risk which the addition of a second source would affect.

Two factors are important in considering risk. The first is the probability of a certain type of risk being realized. The second is the impact that risk would have on a program if it were realized. Combined, these two factors yield the expected outcome, which could be expressed in terms related to output quantity, performance, schedule, or cost.

Dividing a quantity between two producers would not affect the expected outcome--all else being equal. However, the probability that some risks would be realized would be greater with two producers than with one.[2]

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[1]Risk is used in the colloquial sense to include both risk (where probability is known) and uncertainty (where probability is not known).

[2]If there were a 90 percent probability that a given firm would produce all of its allotment and 10 percent that it would produce none, the expected output of either one or two firms attempting to produce a total of 1000 units would be 900 units (.9 x 1000 + .1 x 0 for one producer and .81 x 1000 + .09 x 500 + .09 x 500 + .10 x 0 for two). All probabilities for a particular case must sum to unity. If two producers were involved, their combined probabilities would be the product of their individual probabilities: (.9 + .1)2, in this example.

The nature of weapon systems acquisition programs and the problems they experience are so diverse and dynamic that it is impossible to prescribe probabilities and impact distributions to the risks they face. Nevertheless, it is reasonable to expect that, in general, dual sources would affect only risks associated with factors of production (i.e., land, labor and capital), as duplication would occur for them. Conversely, there is no reason to expect that establishment of a second source would affect other problems experienced by weapon system acquisition programs but unrelated to factors of production.

## TYPES OF RISK AFFECTED BY SECOND SOURCES

Risks associated with various factors of production may cause inadequate performance, schedule delays, and/or cost overruns. These problems are often interrelated. For example, difficult performance requirements sometimes may be achieved by extending the development period and/or paying a higher development cost. A Rand study noted that performance appeared to be the dominant goal in system acquisition, that schedule goals held a slightly lower priority, and that cost increases were apparently accepted to meet performance and schedule goals.[3] Of course, the main objective of dual source competition is to reduce procurement costs. As discussed in Chapter III, there is no reason to assume that procurement costs would be lower under dual source competition than under sole source procurement, and reduction of the kinds of risk identified below could have an indirect effect on cost as well as on performance and schedule.

The following types of risk are associated with the factors of production potentially affected by the addition of a second source:

- Technical - Two types of problems are associated with technical risk: The design of an item might have flaws or problems might arise in the production of a sound design. Technical risk is of key concern initially because, if an adequate design cannot

[3]Robert Perry, Giles K. Smith, Alvin J. Harman, and Susan Henrichsen, *System Acquisition Strategies,* The Rand Corporation, R-733-PR/ARPA, June 1971, p. 9.

be developed and produced in required quantities, then consideration of other types of risk is moot.

- Management - Several concerns exist regarding management: its general ability, its ability to keep the firm operating profitably (in order to avoid bankruptcy), its capability for the successful operation of a production program of the proposed size and complexity, and the potential for loss of key personnel.
- Labor - To meet production requirements, it is essential to have a qualified labor force available and for that labor force to remain on the job. Thus, the supply of required skills in the relevant geographic area and the probability that a significant strike will occur during the production period must be considered.
- Plant and Capital Equipment - Production facilities could conceivably be destroyed by a variety of means, including: natural events (e.g., wind, flood, lightning, earthquake, cyclone), accidents (e.g., fire, radiation, collision with aircraft), and sabotage or vandalism.

The following discussion provides a perspective on the nature, frequency, and potential severity of each type of risk identified above. When they differ, effects on risk of second sources producing identical or alternative items are noted. Methods for evaluating some specific concerns are suggested and supported by examples from analyses related to the cruise missile engine and guidance system, as appropriate.

## Technical

It is not surprising that technical problems occur most often for programs which seek a significant technical advance over a long period of time. The greater the advance and the further in the future it is sought, the greater the uncertainties involved. Since dual sources are contemplated for introduction during the production phase, they would not significantly affect technical uncertainty related to the long term development of items calling for major technical advances.

Problems are often encountered in producing large quantities of an item following prototype production because prototype and full scale production methods are usually quite different. The first few articles of an item normally are built as part of the development program to enable technical and operational test and evaluation. Such prototypes are typically produced in a model shop environment using soft (general purpose) tooling which lacks tolerance limits required for high production rates or long production runs, and by technicians who have more extensive skills than assembly line workers. Thus, progressing from development to full scale production often requires a complex series of adjustments involving interactions between an evolving design, and the use of hard tooling and assembly line labor. Problems requiring solution through innovative manufacturing technologies are often experienced during this transition.

Dual sources producing identical items would have different effects on technical risk than dual sources producing alternative items. Two firms manufacturing identical items would probably contribute different backgrounds and capabilities to complement one another in solving production problems through the formal exchange of technical data. These broader joint capabilities might also serve to mitigate any design problems experienced after the item is put into service. However, they would not reduce the probability of cost, schedule, and quality problems related to flaws in the design.

Two firms producing different designs would reduce the probability of experiencing technical problems associated with a single design and the two production processes would reduce the likelihood of production problems delaying the entire program. The producers would not, however, be able to aid each other in solving problems.

It is impossible to generalize regarding the probabilities of catastrophic technical problems (in either design or production) being experienced because, as stated previously, they are largely driven by the advancement sought and the time available. The probability that some problems would be experienced is close to one, but whether they would be of major consequence is unknown for the general case.

The nature of the technical risk addressed regarding the cruise missile (F-107) engine provides some useful insights. In seeking a second production source for the F-107 engine, the JCMPO was primarily concerned about the Williams Research Corporation's lack of experience in producing the required quantities of an engine of comparable complexity. There was no particular concern regarding the adequacy of the F-107 design per se. This relative confidence in the engine's performance was based largely on its successful completion of the Preliminary Flight Rating Test and Critical Design Review.

Since the existing design for the cruise missile engine was viewed as sound, there was no justification on those grounds to proceed with the development of an alternative cruise engine. When WRC agreed to a leader company procurement, establishment of a second source assured (in theory) the provision of competition and the reduction of other types of risk. Additional discussion of the decision to select a second production source for the F-107 engine was presented in the second chapter.

### Management

No one familiar with the successes or failures of enterprises of all types would deny the importance of management. Yet, although the importance of management is widely recognized, it has received relatively little emphasis during the evaluation of competing proposals: Technical and cost criteria continue to dominate the award process. One reason for this may be the difficulty in defining or measuring "good management." Certainly, the historical performance of a firm may be one measure, although poor performance may have resulted from external conditions beyond management's control and good past performance may not be predictive of future success in endeavors requiring the firm to enter new markets or to produce larger quantities of different products.

In general terms, risks associated with management are related to its ability (however defined) and to the loss of key personnel. Competition between either identical or alternative items would involve two firms and, therefore, two managements.* Thus, risks associated with

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*Under leader company procurement, the management of the initial

a sole source management would be reduced similarly by either type of second source.

The initial source for the RMUC for the cruise missile guidance system, Litton Guidance and Control Systems, had a long and successful record as a defense contractor and there was no abnormal concern regarding its management. However, since the initial source for the cruise missile engine, Williams Research Corporation, had not previously produced a large quantity of an engine of comparable complexity, concerns were expressed regarding the ability of its management to conduct such a large program and, also, regarding the loss of key personnel.

Coincident with JCMPO concerns related to WRC management, Lieutenant Colonel (then Major) Robert L. Taylor of the Air Force Academy had been developing a conceptual framework for assessing the management of defense contractors.[5] He made a thorough review of the organizational structure and management of WRC on the basis of 30 interviews conducted with WRC managers, directors, and employees and, in addition, 36 responses collected from upper-level managers to a questionnaire concerning the organizational climate at WRC. He found WRC to be a superlative organization.[6]

Other interviews were held with WRC's top management to determine its capability for dealing with the large growth that would occur when the F-107 engine reached full production and for managing a production program of the required magnitude. A review was also made regarding WRC's potential loss of key personnel. No unusual problems were found in either case. Thus, while it still would be necessary for WRC to demonstrate its management ability during full scale production of the F-107 engine, no causes for concern, other than its lack of a proven

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source would have a role in the production of the second source if it had the second source under subcontract. Thus, it could conceivably make decisions (such as restricting access to required information) which would affect the second source.

[5]Lt. Col. Theodore Helman and Maj. Robert L. Taylor, "A Conceptual Model for Evaluating Contractor Management during Source Selection," *National Contract Management Journal*, January 1977.

[6]Maj. Robert L. Taylor, "Williams Research Corporation," *Business Review of Organization Structure and Management*, Department of Economics, Geography, and Management, U.S. Air Force Academy, 15-17 June 1977.

record, surfaced during the various evaluations which were held and no need for special actions to bolster this area, related to a second source or otherwise, was identified.

Another critical factor related to management ability is the financial stability of a firm. The JCMPO initiated financial stability reviews for all key cruise missile contractors to assess their financial structure and consider their sensitivity to assumptions about ranges of sales in various markets. These reviews were aimed at identifying potential external problem areas that might affect a firm's ability to produce cruise missile components. While the initial reviews did not uncover any unusual financial risks for the initial sources, they did provide an analytical framework and identified issues to be monitored during the course of the program.

Thus, while the importance of good management is undisputed, evaluating it is difficult. Several issues potentially applicable to other programs where there is concern about a particular firm's management were considered by the cruise missile program. It is, however, nearly impossible to provide a general assessment of management risk because of the great variance among firms and because the effects of poor management may be realized in so many different ways.

### Labor

An item cannot be produced unless a capable labor force is available and on the job. Thus, the two primary issues associated with a firm's labor force are the availability of a sufficient supply of qualified personnel and the probability of a work stoppage due to a strike or similar action.

The availability of a qualified supply of labor has not been a recurring problem for previous defense programs and is not likely to pose a significant problem in the future, although individual problems could arise from a variety of causes. For example, a firm's business could grow more rapidly than the supply of available labor or certain barriers could restrict new labor from entering a particular area (e.g., Southern California real estate prices). There are numerous precedents for surveys of available labor, so this issue may be resolved for individual cases where it is of concern.

The main risk related to labor is that a work stoppage could cause major schedule problems and result in related added costs. The Bureau of Labor Statistics (BLS) collects relevant data concerning work stoppages; its *Handbook of Labor Statistics* (1977) indicates that, between 1967 and 1975, work stoppages for all manufacturing resulted in a loss of only 0.45 percent of total working time. Other BLS reports provide more detailed information by year and industry. For example, the information shown below, in Table 4.1, for 1975 and 1976 was taken from *Analysis of Work Stoppages, 1975* and from *Work Stoppages, 1976,* respectively. While there is some variance by both year and industry, it does not differ too greatly from the overall average stated above. Further inquiries were made of BLS concerning the standard deviation about the mean number of days per stoppage; such information, however, was not available. Non-union work stoppages accounted for only 0.8 percent of the total. Thus, while the risk of work stoppages is generally low, it is much greater for union than for non-union plants. Although this information is several years old, it was confirmed that it is still generally applicable.

Individual work stoppages can cause significant problems and examples of this abound. F-15 and F-16 fighter aircraft were recently grounded while awaiting repair or production of their Pratt & Whitney F-100 engines which were delayed by strikes at two engine subcontractors (the Fafnir Corp., which makes bearings, and the Ladish Corp., which makes castings). This indicates that work stoppages even at the vendor level can cause significant problems. It is, therefore, advisable to secure back-up suppliers for key components whenever the costs of doing so are not excessive in comparison with the risks of not doing so.

Unlike the types of risk discussed previously, potential labor problems are not necessarily affected by the type of second source (identical or alternative item) or even by the number of firms involved. This is because most stoppages are associated with unions, which organize plants rather than firms. Thus, a firm with two plants could have zero, one, or two unionized plants. Similarly, two firms could each have a plant under the jurisdiction of a single union.

Table 4.1

WORK STOPPAGES BY YEAR/INDUSTRY

| | Work Stoppages | | | Days Idle During Year | |
|---|---|---|---|---|---|
| Year/Industry | Number | Mean Duration (Days) | Workers (000) | Number (000) | % of Total Work Time |
| 1975 | | | | | |
| Manufacturing machinery except electrical | 274 | 37.4 | 74.4 | 2,370.8 | 0.45 |
| All manufacturing | 1,897 | 37.9 | 463.8 | 14,876.1 | 0.32 |
| 1976 | | | | | |
| Manufacturing machinery except electrical | 309 | 23.2 | 144.5 | 2,721.0 | 0.52 |
| All manufacturing | 2,245 | 32.3 | 974.5 | 24,263.1 | 0.51 |

While the probability of a work stoppage is low and the average number of days lost when one occurs is tolerable, examples of problems resulting from work stoppages still abound. Moreover, it is difficult to forecast such problems accurately, except when a union contract is up for renewal. In any case, this risk may not be affected by the presence or absence of a second source.

## Plant and Capital Equipment

The destruction or severe disablement of the facilities of a sole source could cause major delays, resulting in added costs for a given program. Facilities could be severely damaged through a variety of natural, accidental, or deliberate events.

Determining the probability that facilities would be damaged is not easy. It was, however, felt that a review of industrial insurance policies might provide some useful insights because an insurance company in essence "gives odds" against facility damage from a variety of

causes. For example, a typical industrial policy covers loss due to: fire, wind, water damage (excluding flood), and vandalism/malicious mischief. The rates shown in Table 4.2 are for National Board Class C (stone, brick, or similar construction) buildings outside the central city similar to the WRC plant at Walled Lake, Michigan.

It was learned that the premium includes approximately the following: 15 percent commission, 15 percent administration, and 70 percent for loss that year and reserve for future loss. Approximate probabilities of loss may be estimated by dividing 70 percent of the premium into the amount of the coverage. These range from about 200:1 to 300:1 for equipment and buildings, respectively. It is likely that this probability is overly conservative because it includes relatively minor potential losses (e.g., damage from a brick thrown through a large window or smoke damage from a small fire) that represent a substantial portion of claims actually paid. There was no basis for estimating only those losses serious enough to affect production. However, this may be offset by the fact that policies usually exclude damage due to such causes as earthquakes and acts of war.

Thus, the probability of damage to the facilities of a sole source appears similar to that of a work stoppage (about 0.5 percent), and the severity of the incurred damage could range from insignificant to catastrophic. In the event of severe damage, the existence of either type of second source would enable production to continue. However,

Table 4.2

SAMPLE INDUSTRIAL INSURANCE PREMIUMS
BY AMOUNT OF COVERAGE

| Amount of Coverage ($M) | Annual Premium (Building) | Annual Premium (Equipment) |
|---|---|---|
| 0.5 | $ 2,480 | $ 3,520 |
| 1.0 | 4,920 | 7,000 |
| 1.5 | 7,360 | 10,480 |
| 2.0 | 9,600 | 13,960 |
| 5.0 | 24,440 | 34,840 |

remaining equipment could be pooled to mitigate the effect of the damage in the case of two sources producing an identical item.

### Summary

While it is rare, if not unheard of, for an acquisition program to be conducted without experiencing technical difficulties, schedule delays, and/or cost overruns, these problems are typically caused by reasons other than those related to the factors of production which would be bolstered by establishment of a second source. Nevertheless, dual sources would decrease somewhat the relatively low probabilities that inadequate performance, program delays, and resultant higher costs would occur because of certain problems associated with the technical information, management, labor, and/or plant and capital equipment of a sole source. The type of second source established would probably have a significantly different effect only on technical risk: Two sources producing different designs would provide protection against design problems while two sources producing identical items would provide protection against production problems. Although there may be subtle differences between the two types of second sources for other risks, they do not appear significant. Even though the effect of two sources on performance, schedule, and cost problems is not seen as being great enough to support their establishment as a general policy, it might be desirable to establish a second source to reduce an area of unusual risk associated with a particular sole source, if it could be done in a cost/effective manner.

## OTHER ISSUES

Other reasons for establishing dual sources should also be considered, in addition to implementing competition and reducing risks associated with a sole source. Two such reasons are the enhancement of industrial mobilization and the provision of certain operational advantages. Each of these issues is discussed below.

"Mobilization" as the term is used by the defense establishment means the act of getting ready for war. This implies achieving industrial output significantly greater than normal. To achieve

increased output in a short time period (surge capability), it is necessary to have excess production capacity throughout the several tiers of subcontractors and vendors involved in producing a particular system to prevent bottlenecks. It is possible to make a general assessment of the unused capacity within the various sectors that comprise the defense industry.[7] However, whether the production of key weapon systems may be increased depends primarily upon the availability of unused capacity on specific equipment and tooling, and upon the existence of an adequate supply of trained labor. As discussed in the third chapter, some excess capacity is a requirement for dual source competition, as each source must must be capable of producing the portion of an item equal to the largest possible annual award. Hence, long lead times to obtain necessary equipment would be avoided to some extent.

Industrial mobilization has long been recognized by the government as a factor to be considered in the procurement of goods. As noted in the second chapter, competitive negotiation may be used in lieu of advertising only when specific exceptions exist; the exception most commonly cited to justify competitive negotiation is industrial mobilization.

Thus, mobilization may provide a reason (in addition to price competition or risk considerations) for establishing dual sources. Several situations might justify dual sources, either based solely on mobilization or in combination with cost and/or risk considerations. When the planned production rate forms a substantial share of one firm's capacity, or when a winner-take-all award may drive unsuccessful competitors out of a vital defense industry, it may be desirable to spread production between two or more firms. Splitting production awards may be especially desirable in cases where the planned production rate would require expansion of one firm's capacity in the face of excess capacity available at other firms.

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[7]A methodology for performing such an analysis and an assessment of industrial capability for handling a large surge in DoD demand is provided in Michael D. Miller's *Measuring Industrial Adequacy for a Surge in Military Demand: An Output-Out Approach*, The Rand Corporation, R-2281-AF, September 1978.

If substantial commercial applications of the item procured by the government are anticipated, it may be desirable to increase the number of available sources immediately in order to assure supply and to avoid the establishment of a monopolist with a lucrative alternative to government contracts.

Another reason to establish dual sources could be the inability of any single supplier to produce at required rates without overburdening its management and administrative capabilities, overloading its production facilities, or overdrawing the labor pool in its region. In certain cases, excess concentration of work at a single facility could cause severe social disruptions in the surrounding community, due to the initial immigration of thousands of workers and by their later layoff and subsequent dependence on public funds when the program ends.

While there may be ample reasons to establish dual sources for considerations of industrial mobilization, they would have to be analyzed independently for each case. Factors to be considered should include, among others: the importance of a weapon system to the national defense, the substitutability of a particular component within the system, the lead time required to obtain additional plant and capital equipment, the availability of additional skilled labor, the effect of peacetime production requirements on the local economy, the distribution of work within a particular industry or segment of industry, and the potential that a sole source may substitute more lucrative commercial business for defense business.

Finally, it is critical that the system be considered as a whole so that the mobilization capability for some components is not assured at added expense while that for others is neglected, causing potential bottlenecks. For example, even if a mobilization capability is assured for cruise missile airframes, engines, and avionics (all of which are acquired by DoD), the missiles still could not be deployed unless a comparable mobilization capability is assured for the warhead (which is produced through the Department of Energy).

The establishment of dual sources also could enhance the operational effectiveness of certain systems. This is most likely with alternative items utilizing different technologies. For example, there

have been cases where two technologies require the enemy to employ different countermeasures and thereby double its efforts in a particular area. Thus, by utilizing an alternative item, and perhaps paying a slightly higher life cycle cost, the probability of success for a particular mission might be enhanced, with risk reduced and mobilization facilitated as spinoffs.

Although the expectation of effecting cost savings through competition has been the primary motivation for establishing dual sources, other reasons exist which may justify dual sources in particular cases. None of these other reasons (including risk, mobilization, and enhanced operational capabilities) are seen as providing justification for mandating dual sources across the board. However, analysis of certain situations may lead to the conclusion that, even when additional costs are required to establish dual sources, the additional expenditure would be an effective investment.

If the savings anticipated from competition between dual sources are significant, or if the establishment of dual sources is seen as desirable because of risks identified for a particular sole source, mobilization requirements, or operational enhancement regardless of anticipated added cost, then the decision is relatively straightforward. However, making a decision in the absence of a single dominant factor may be difficult.

# V. SUMMARY AND CONCLUSIONS

The establishment of two production sources is currently receiving the attention of DoD decisionmakers who see it as a means of maintaining competition throughout the procurement phase of a program in order to minimize costs. It is also felt that two production sources would reduce certain risks associated with a sole source and thereby enhance the probability that the government would obtain new weapons which meet performance specifications on schedule and for the estimated cost. The vagueness of the expectations concerning competitive cost savings and reduction of risk suggested that a theoretical and empirical examination of them would be useful. Therefore, this study addressed cost and risk issues associated with the establishment of second sources and the implementation of dual source competition to identify important considerations regarding the application of this emerging policy.

Since the most common reason given for establishing dual source competition is the expectation of cost savings during production, this study examined relevant economic theories and analyzed available data. Economic theories did not provide a rationale for assuming that dual source competition would consistently lead to lower costs than would a negotiated procurement from a sole source. Rather, they indicated that it is more efficient and, therefore, less costly for one source than for two to produce the entire quantity of an item because a single source can: effect economies of scale; fully utilize production capacity; amortize fixed indirect costs over a broader base; and maximize learning. Also, duopoly theory indicates that each producer will consider the effect it will have on the market and on the other producer in developing a sales strategy. For example, a duopolist may maximize profits either by selling the largest possible quantity or by setting a higher price for the quantity demanded beyond the initial firm's capacity to supply. Thus, efficiency is not a condition for profit maximization under dual source competition.

Even though theory provided no basis for assuming that production cost savings would result from dual source competition, it did not eliminate the possibility. Therefore, available data on competition were collected and analyzed. Ten cases were identified where split-buy competitions had been held. Added costs or savings due to competition could be estimated for seven of those cases and it was found that four of them showed increased costs. Furthermore, savings or added costs during recurring production were offset or increased when establishment and qualification of a second source required substantial nonrecurring costs.

Items procured through annual winner-take-all competitions also yielded significant cost data. Of the 18 items for which the effect of winner-take-all competition could be estimated, 17 showed savings. Since the government generally held winner-take-all competitions between firms with existing production capabilities, the competitors did not require allocations for nonrecurring costs.

Thus, all types of competition do not produce the same results: Winner-take-all competitions usually result in savings; split-buy competitions often increase costs. Split-buy competitions involving relatively simple items with high quantity requirements and a sole source with a shallow learning curve slope appeared to be more successful than those involving complex items, low quantities and an efficient sole source.

Since no basis was found for assuming that dual source competition will generally result in lower costs, it should not be implemented as a general policy for this purpose. Nevertheless, when favorable conditions exist, it may be appropriate to establish dual source competition.

A secondary reason often given for the establishment of a second source is that dual sources would reduce risks associated with a sole source. However, no one had previously identified the type of risks related to a sole source which the addition of a second source would reduce nor considered potential impacts of the risks on system performance, schedule, and costs.

It was found that a second source would reduce the probability that some risks related to the factors of production (technical, management, labor, and plant and capital equipment) would result in a program's disruption. However, those risks which the establishment of dual sources would reduce are not usually major contributors to inadequate performance, schedule delays and cost overruns. Therefore, the reduction of risk does not provide a sound reason for establishing second sources as a general policy.

Finally, dual production sources may serve to maintain the country's industrial mobilization base both in general terms and also for a particular weapon system. This may be a particularly attractive benefit at a time when U.S. industrial preparedness is being seriously questioned. However, it is necessary to consider mobilization in an appropriately broad context to avoid suboptimization for some subsystems while bottlenecks remain for others.

Activities related to the selection of second sources by the cruise missiles program underscore many of the findings of this study. The fact that second source activity did not begin until the program was well into full scale development proved a major constraint. Initial sources for key subsystems claimed rights in proprietary data to strengthen their negotiating positions when confronted with the establishment of second sources.

The Williams Research Corporation was able to choose the second source for its engine and to have it serve as its subcontractor under a leader company procurement. The only other second source options available to the government in this case would have involved long legal actions to establish data rights or else the development of an alternative cruise engine. Both options would have meant a significant delay in achieving dual source competition. Its agreement to supply data to another firm enabled WRC to deny a competitor between $70M and $100M for designing a comparable engine and to limit the cruise missiles program's use of its data. Thus, it was able to maintain an advantage in the broader marketplace.

In the cruise missile guidance case, competition took place to determine whether the second source would produce an alternative or an identical reference measurement unit and computer. The initial source, Litton Guidance and Control Systems, proposed to establish another Litton division, Litton Systems Limited, as the second source at no cost to the government. Its primary competitor, Singer Kearfott, argued that this did not constitute competition. Nevertheless, competition during production became a somewhat secondary issue when the government found itself faced with a choice between a potential second source with no nonrecurring costs and another with between $40M and $60M in nonrecurring costs. The government elected to avoid initially higher costs and Litton was thereby enabled to remain as a "monopolist" for the cruise missile RMUC even though production would be divided between two of its divisions.

Risk analyses were performed regarding the sole sources for the engine and guidance system. However, no major problems were identified as determining factors in the decision to establish a particular type of second source.

Although dual source competition does not appear to be a cost/effective system acquisition policy for the majority of cases, it may be appropriate under certain circumstances. Table 5.1 provides a summary of the issues (together with comments when appropriate) which should be considered for items which are candidates for dual source competition. While there are no hard and fast rules to determine when dual source competition should be established, a well organized analysis of relevant issues prior to its implementation should ensure that expectations and results are not too disparate. The weighting of individual issues would depend upon the utilities of the decisionmakers involved in establishing the objectives for a particular weapon systems acquisition program.

Table 5.1

ISSUES TO BE CONSIDERED REGARDING THE ESTABLISHMENT OF DUAL SOURCE COMPETITION

## The Initial Source

If the initial source is an efficient producer, the probability of achieving cost savings through dual source competition is reduced. Therefore, an evaluation of the initial source should be made at the outset.

- Is there a reason to expect that the initial source will not be a cost/effective producer?

- If the initial source has begun production, what is its learning curve slope? (A steeper slope usually indicates an efficient producer.)

- Has the initial source performed acceptably for comparable programs? Does it have a significant history of cost overruns?

## The Item to Be Produced

In general, competition produces greater savings if the government has complete responsibility for selecting a second source and does not require the involvement of the initial source. To accomplish this, the government must have the right to use the data and the item must be sufficiently simple that technical assistance is not required from the initial source. In the absence of these conditions, an alternative item may be required.

- Does the government have the necessary data rights to prepare an RFP for a second source? If yes: Would technical assistance be required from the initial source? Would the initial source be willing to provide it?

- Does an off-the-shelf item exist which might be used as a substitute?

- Does the item to be produced significantly advance the state of the art?

## Nonrecurring Costs Required to Estabiish a Second Source

Added costs are usually required to establish dual source competition. They must be estimated to determine the amount that would have to be saved during production before overall savings can be achieved.

Table 5.1--continued

- What is the estimated cost of obtaining data rights?
- What is the estimated cost of developing a complete technical data package?
- What is the estimated cost of technical assistance from the initial source (if required)?
- What is the estimated cost to develop an alternative item?
- What are the incremental costs of tooling and test equipment for a second source producing an identical item and an alternative item?
- Would added facilities and equipment be required by the second source?
- What added costs would the government incur for items such as second source selection and qualification or for test and evaluation?
- Specify any other nonrecurring costs which a second source might require.

## Quantity and Recurring Production Cost

The time required to establish a second source producing an identical or alternative item may vary. In general, the longer it takes the second source to begin production, the greater the advantage to the initial source because of the learning it will gain in the interim. The total quantity to be produced and the estimated sole source cost provide a basis for estimating the savings required to offset additional nonrecurring costs.

- What is the total required quantity?
- How many units would the initial source produce prior to competition if the second source produces an identical item? If it produces an alternative item?
- How many educational units would the second source have to produce? What would its average unit cost be for those units?
- What is the estimated sole source cost for the quantity to be competed? (The learning curve slope and intercept should be specified.)

Table 5.1--continued

- What savings percentage must be achieved to offset nonrecurring costs? (Added nonrecurring costs divided by estimated sole source cost for quantity to be competed.)

## Risk

Four kinds of risk related to a sole source might be affected by a second source. It should be determined whether unusual concerns exist regarding the sole source.

### *Technical*

- Has the initial source previously produced an item of this complexity in the required quantity and at the required rate?
- Is it likely that the initial design will encounter major problems during development or in production?

### *Management*

- Has the management of the initial source demonstrated the capabilities required for effective administration of this contract?
- Are there one or a few key personnel of the initial source who are critical to the success of this program?
- Is the initial source financially healthy? Are there other areas of its business which might cause problems in the future?

### *Labor*

- Is the labor force of the initial source unionized? If yes: When does the contract expire?
- Is there currently an adequate supply of qualified labor in the geographical area of the initial source to support the production program? Are other firms likely to compete heavily for that labor in the future?

### *Facilities*

- Are the facilities and equipment of the initial source adequate for this job? Is there excess capacity (including suppliers and subcontractors)?

Table 5.1--continued

## Mobilization

It is important to consider the industrial mobilization base in a broad context. However, related issues may also be appropriately considered in the context of establishing a second source for a particular item.

- How long would it take the initial source to increase production by 10 percent, 50 percent, and 100 percent above its planned maximum rate?

- If the production rate of this item is increased, would another item cause a bottleneck with respect to increasing production of the entire system?

## Conclusion

This list provides a general framework of issues that might be relevant to a decision to establish dual source competition for a particular item. Since each case would have unique characteristics, issues should be added, augmented, or deleted as appropriate.

# APPENDIX A

# DATA RIGHTS

The term "technical data" (also referred to simply as data) represents the documentation of special engineering, technical, or manufacturing features incorporated into a firm's design. This documentation includes:

> writings, sound recordings, pictorial reproductions, drawings, or other graphic representations and works of similar nature, whether or not copyrighted. [It] does not include financial reports, cost analyses, and other information incidental to contract administration.[1]

The ownership of rights for the unrestricted use of data is a major determinant of the type of second source (one producing either an alternative or an identical design) available to the government and, therefore, may have significant cost implications. This appendix considers issues related to the ownership and value of technical data and how they may affect the establishment of second sources.

## PROTECTION AND OWNERSHIP OF DATA

Commercial firms usually seek to protect data they have developed at their own expense in order to maintain the competitive advantages resulting from exclusive control or use of that data. There are two general methods of protecting data: patents and restriction of access. A patent is an explicit license to restrict the use of knowledge or techniques, even when fully known to others than the patentee. Full disclosure is, in fact, a condition of the patent grant. Although disputes over patent policy in procurement are frequent, the patent right at least has a definite scope and creates an enforceable claim. Proprietary rights in data, on the other hand, stem from the somewhat cloudy doctrine of "trade secrets." Non-disclosure is the essence of a trade secret, which is in fact valuable only as long as it remains

[1]DAR, 9-201(2).

secret. Disclosure compromises any rights the processor may have. A patent is a monopoly in law; a trade secret is a monopoly only in fact. The law merely allows the originator of proprietary data the right to safeguard its secret and to prevent unauthorized dissemination when it is disclosed to others (including employees) in confidence.

Firms often seek to protect their competitive advantage by keeping their data secret instead of obtaining a patent because, after 17 years, the patent becomes public domain; the trade secret, however, remains proprietary as long as it is a secret. The main disadvantage of a trade secret is that, if it is discovered, it may be used, manufactured, sold, and possibly patented by another firm.[2]

The government formally recognizes the right of contractors to keep secret that data which they have developed at their own expense:

> Such data, particularly technical data, which discloses details of design or manufacture is often closely held because its disclosure to competitors would jeopardize the competitive advantage it was developed to provide. Public disclosure of such technical data can cause serious economic hardship to the originating company.[3]

It also recognizes its own requirement to obtain and use data:

> Data resulting from research and development contracts must be obtained, organized and disseminated to many different users. Finally, the Government must make technical data widely available in the form of contract specifications in order to obtain competition among its suppliers and thus further economy in Government procurement.[4]

When the government seeks to obtain data rights to establish competition, a major conflict often emerges as the contractor seeks to retain the rights to data it views as proprietary and, thus, to force the government to return to it repeatedly for application of the designs and techniques covered by the data.

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[2]Dean Francis Pace, *Negotiation and Management of Defense Contracts,* John Wiley & Sons, Inc., 1970, p. 719.

[3]DAR, 9-202.10.

[4]DAR, 9-202.1(a).

The experience a research and development contractor has obtained by designing, developing, and manufacturing similar items is used in designing new ones. If previous, relevant experience was obtained at private expense, the data rights belong to the R&D contractor. If it was obtained by working on other government projects, the data rights belong to the government. When a contractor's previous experience includes both private and government projects, both ownership of the data and determination of the contribution that data made to the final product are frequently open to disagreement.

Even when the R&D contractor claims no proprietary data rights, technical data may still present a problem in establishing a second source because parts and components, whose vendors have proprietary information of their own to protect, may have to be included at either the R&D or production stages. When data rights are disputed, significant costs and/or schedule problems may result.

## VALUE OF DATA

If the government does not acquire unlimited rights "to use, duplicate, or disclose data in whole or in part, in any manner and for any purpose whatsoever, and to have or permit others to do so," in the development contract, it may pay a substantial penalty when the production phase approaches, if the contractor claims proprietary rights to the data. This penalty may be felt in terms of schedule, if production is delayed by litigation, and/or in terms of cost, if the government buys the rights, pays for the development of an alternative design, or engages in "reverse engineering" by determining design and process data from the product itself.[5]

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[5]Reverse engineering is exceedingly difficult to accomplish for complex systems. Stories abound concerning failed attempts to create designs by examining and analyzing an actual item. Many reasons are given for this, including failure to recognize numerous and complex interactions and the fact that the production of many components is as much an art as a science. This latter point is supported by the fact that there have been relatively few successes in producing technically complex systems from plans and drawings alone, even when those plans and drawings are produced by the developer.

The upper limit that the government should be willing to pay to obtain unlimited data rights would be represented by the cost of developing an alternative item or the cost of reverse engineering (whichever is lower) less any reduction in system acquisition costs reasonably expected as a function of subsequently implementing competition.[6] It is noted that these costs are difficult to estimate with acceptable accuracy for complex systems.

The value of proprietary data rights to the developer is the probable value of business potentially lost if the information were freely available to its competitors. The contribution of the military market to the value of the proprietary rights depends on the elasticity of the government's demand for the product. If the item has a commercial as well as a military market, the contribution of the commercial market to the value of the proprietary data rights generally depends on the costs and on the item's market value as limited by the monopolistic competition provided by its rivals.

Where commercial uses are involved or anticipated, the value of proprietary data rights to the developer could exceed the value placed on them by the government. Also, developers often exaggerate the value of their rights and hold on to them at any price that the government is willing to consider, even when there are no commercial applications presently in sight. Thus, a technologically progressive firm selling only a narrow range of products and services may well quote the total present value of its enterprise as the price for its proprietary data rights. In short, the nature of the defense supply industry provides no reason to expect a brisk market in proprietary data rights.[7]

Even if legal and financial obstacles concerning proprietary design data are overcome, the development of a technical data package during the R&D phase to enable an outside source to produce a complex item without assistance from the developer is difficult for many reasons, including the following:

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[6] James A. McKie, *Proprietary Rights and Competition in Procurement*, The Rand Corporation, RM-5038-PR, June 1966, pp. 23-24.

[7] McKie, Proprietary Rights, pp. 26, 27.

- Effectively managing highly detailed technical data is a difficult task;
- Errors may exist due to design changes, oversight, or lack of incentive on the part of the developer;
- Information may be excluded because it is regarded as common practice by one firm, although not by another;
- Design modifications made during initial production would be omitted;
- Additional proprietary elements related to production may be introduced after the R&D phase.

Thus, even if the government owns the rights to all proprietary data related to the design of and manufacturing processes for an item, technical assistance by the developer may still be required to establish a qualified second source.

# APPENDIX B

# ESTIMATING COSTS RELATED TO THE ESTABLISHMENT OF SECOND SOURCES

The expectation of recurring production cost savings is the main reason for implementing dual source competition. However, other life cycle cost (LCC) elements are also affected by establishing second sources. This appendix identifies general techniques available for estimating costs and suggests problems and methods related to estimating key cost elements within each LCC category.

## COST ESTIMATING TECHNIQUES

Three types of cost estimating techniques (analogy, parametric, and industrial engineering) may be used to estimate the costs of establishing second sources. Analogy cost estimates may be called for if only limited historical cost data are available for items similar to the one being considered. Parametric cost estimates are based upon finding meaningful relationships between physical and/or performance characteristics and costs. These techniques are based on the assumption that experience is a reliable guide to the future: that the known may be used to forecast the unknown. A detailed industrial engineering cost estimate may be appropriate if the item involves key components which are not represented in past experience or if the acquisition process has progressed to a stage where a substantial amount of information is available.

### Analogy

Analogy is essentially a judgment process which relies on experience. It is generally applied (and its applications should be restricted) to cases where data are severely limited. This may, however, be done with sufficient accuracy when data related to the single element and knowledge about the specifications of the proposed

element are adequate to make statements about key similarities and differences concerning physical characteristics and required performance. From these statements, it becomes possible to make assumptions as to how cost will be affected and to make an estimate. It is essential to define the assumptions clearly and to ensure that they are at a level sufficiently low to allow examination in detail of the sensitivity of the estimate to them.

### Parametric

Parametric cost estimating techniques rely on the discovery of relationships between cost and physical and/or performance characteristics. The successful application of parametric cost estimating techniques requires the existence of three factors:

- A real dependence between cost and values of parameters that can be postulated and expressed in quantitative terms;
- Cost experience relevant to the problem at hand that can be used to test and calibrate the postulated cost and dependence;
- Sufficient confidence in the validity of the cost dependence pattern derived that it may be reasonably extended to the new item.

### Industrial Engineering

Industrial engineering cost estimating techniques are sometimes referred to as "grass roots" estimating. They are implemented at the lowest level of detail, as the estimator specifies each engineering task, tool requirement, and production operation (including required labor) based upon a set of detailed drawings. When ordinary operations and equipment will be required, standard cost factors may be applied. If new techniques are to be used, cost factors must be developed.

Industrial engineering estimates require an extraordinary amount of manpower to develop, an expenditure not warranted for many purposes. When used during the early stages of a program, industrial engineering techniques are often less accurate than analogy or parametric methods

because they depend on identification of all of the components and on relatively accurate estimates being made for each. This often does not represent the total cost of an item, which is typically greater than the sum of the costs of its component parts because of certain high level phenomena. (Engineering change orders are an example.) Nevertheless, when no relevant high level data are available to support the application of analogy or parametric techniques, an industrial engineering estimate may be required.

## LIFE CYCLE COST CATEGORIES

One or more of the cost estimating techniques described above may be required to make reasonable estimates of cost elements which would be affected by the establishment of a second source. The general effects of second sources on each life cycle cost category and potential sources of data for use in estimating costs are discussed below.

## RDT&E

The estimation of research and development costs is a particularly complex problem because there may be no logical relationship between previous experience and the current problem, if new technology must be created. Even if the required technology exists, it is frequently impossible to predict difficulties in adapting it to produce a specified product. Finding meaningful cost data presents another problem. Frequently, R&D contract data (even if well defined) may understate the true total cost significantly, since the contractor may have paid for part of it with its own funds (anticipating a commercial payoff or underwriting R&D as part of the overall cost of competition) or it may have benefited from other, complementary programs.

The problem is somewhat reduced, however, when R&D is estimated for a second source. If a firm is required to produce another firm's design, R&D costs would be essentially nil. If an alternative design is sought, the R&D expenditures for the initial source may serve as a baseline and assessment would be required regarding the similarities and differences between the alternative designs and the contractors' capabilities. Another source of R&D cost data may be proposals, since more than one firm generally participates in the initial R&D

competition. Of course, proposals should be regarded skeptically when used as sources for cost data. Nevertheless, they may prove meaningful when their data are related to actual experience.

Test and evaluation costs (in both the R&D and operation and support phases) are driven primarily by the government. Their unit costs may be estimated with relative accuracy, since fairly reliable government records are kept for both subsystem and system level costs. Determination of the number of tests the government will require presents the major problem, since practice is not prescribed by policy and often appears to have been determined arbitrarily.

### Nonrecurring Investment

Estimating nonrecurring investment costs presents a problem which is similar in many ways to that of estimating R&D costs. Nonrecurring investment costs may vary greatly among contractors, depending on each contractor's existing capabilities and policies regarding capitalization of expenditures for equipment common to its other products. Again, the initial contractor's experience represents a base case and other data may be obtained from proposals.

### Recurring Production

The most difficult cost estimating problem for second sources is presented by recurring production, in spite of the fact that the most complete and detailed data are generally available for hardware and that there are useful theories to aid in determining how costs will vary in accordance with production quantity and rate. The problem is that there is neither adequate data nor theory regarding how the constrained form of competition proposed for dual sources will affect cost. (Related economic theory is discussed in the third chapter.) Since recurring production costs represent by far the largest portion of total life cycle cost for a subsystem, the analytical methodology provided in this report concentrates on estimating the costs of the other LCC categories and then on determining how great the recurring production cost savings would have to be to break even in comparison with the estimated sole source recurring production cost.

**O&S**

Support costs are usually estimated by a model based upon the various activities (e.g., transportation, training, storage, maintenance) performed after an item is deployed. Such models include factors developed from years of experience with similar items. The main problem in estimating the O&S costs associated with second source alternatives is making reasonable assumptions which do not favor one of them. Therefore, it is important to analyze all support alternatives when they would lead to significantly different results.

Given the existing state of the art of cost estimating techniques, it is possible in most cases to make reasonable estimates of those cost elements which would be affected by the establishment of a second source. Such estimates would enable a determination to be made as to whether a dual source competition is likely to yield sufficient savings associated with recurring production to offset added costs associated with other categories.

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